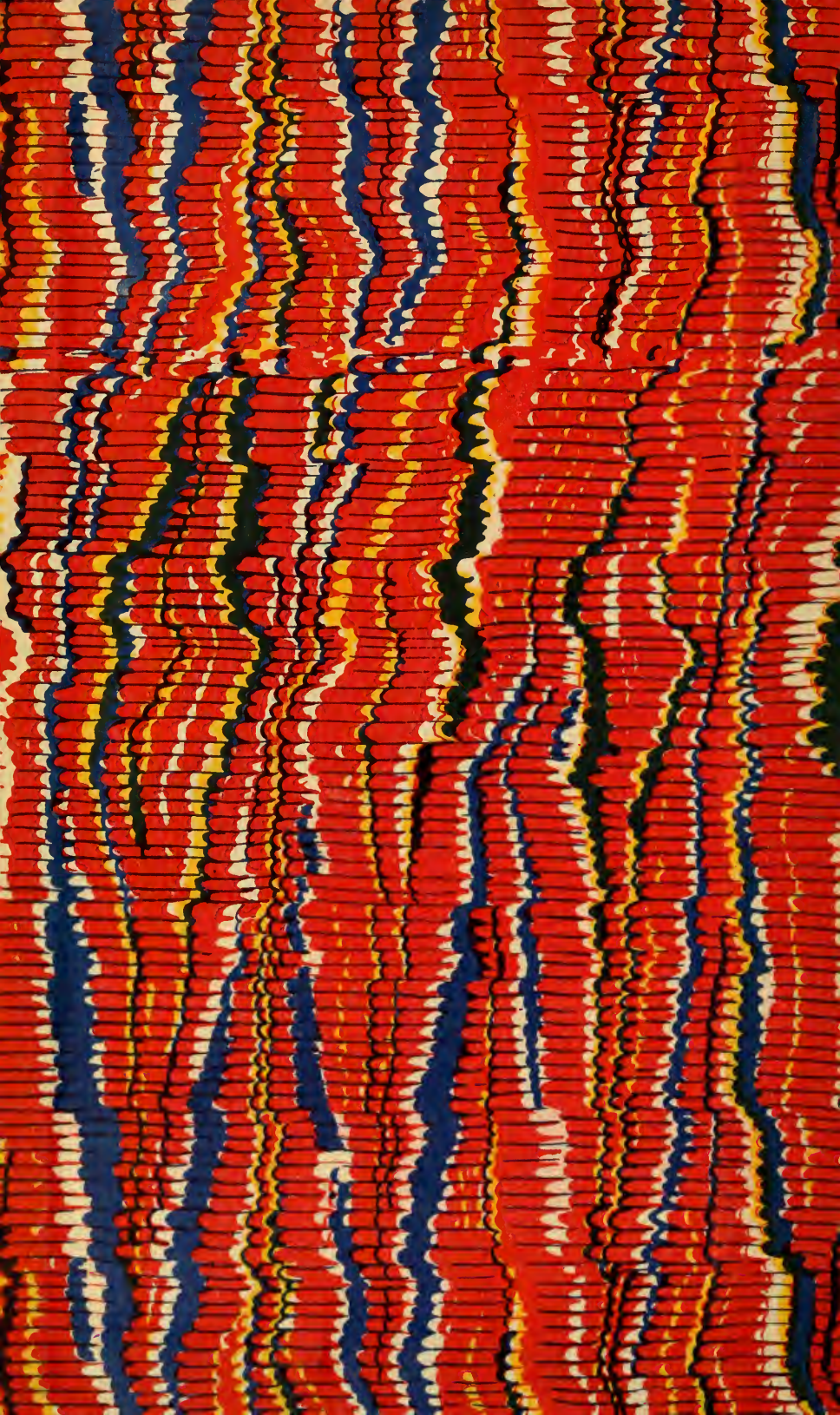






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Insects



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A STUDY OF THE BEHAVIOR OF BEES IN
COLONIES AFFECTED BY EUROPEAN FOUL-
BROOD¹

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INTRODUCTION

The brood diseases of bees cause annually large losses of bees and consequently of the honey crop. The predominant attitude among beekeepers has long been how best to eradicate an invading bee disease after the attack has been made. They depend upon this procedure, because little is known with any degree of certainty concerning the natural conditions which might prevent or control the onslaught of the disease. As a result of this attitude, much more importance has been placed on the significance of apiary inspection and police-power laws and of purely remedial treatment, the reasons for which in many cases are imperfectly understood. But the old adage "an ounce of prevention is worth a pound of cure" has yet to be refuted, particularly with regard to beekeeping. In the realm of human

¹ A series of investigations was started in the spring and summer of 1918 by the Office of Bee-Culture Investigations, Bureau of Entomology, for the purpose of making an intensive study of European foulbrood of bees, primarily from the standpoint of insect behavior in relation to the disease, correlated with the facts and practical observations already known to the beekeeper. This paper, which was submitted for publication January 13, 1919, is a preliminary report on the beginning of the investigation.

medicine, for the last two decades at least, this precept has been gaining strength so that to-day preventive medicine stands on a par with, if not above, most of the other branches of medicine. Why is it not logical to apply this principle to the control of bee diseases?

Ever since European foulbrood of bees was first recognized (in 1894), in New York State, as a distinct brood disease, there have been much controversy and speculation concerning the etiology of the disease, the means of transmission, the method of spread, and, resulting therefrom, the question of control. From the laboratory standpoint, the etiology of the disease has been worked out quite definitely bacteriologically (12)¹. But as yet *Bacillus pluton*, the accepted cause of European foulbrood, never has been grown in pure culture on artificial media, although it has been definitely identified as the cause of the disease. This precludes any further advance along this line of attack for the time being.

From the side of practical experience, there have been recorded large numbers of observations, many of them of a similar nature. These observations have led to many accepted practices, as, for instance, the use of Italian bees and strong colonies in combating the disease. Although the weight of numbers tends to give substantiation to observations, the scientific explanation of how these things are true never has been studied carefully and coordinated with the practical side into an epidemiological study of the colony under disease conditions in European foulbrood.

The history of bee diseases has developed mainly along two lines. The scientific side has been concerned principally with determining the causes of the various diseases microbiologically, the method of diagnosis, and conclusively differentiating them. These facts have been described sufficiently in various bulletins of the Bureau of Entomology and will not be discussed here. From the practical side, countless observations have been recorded, largely in the bee journals, in which various manifestations of the disease and experiences with methods of treatment have been discussed. But in all this literature, particularly with regard to European foulbrood, there are few observations on the disease and on the behavior of the bees in relation to it beyond simple description of symptoms.

Early in the experience with European foulbrood it was learned by careful observers that strong colonies are essential in successfully combating the disease. Later the value of Italian bees was discovered. West (11), a New York State apiary inspector, in giving what is one of the best early descriptions of European foulbrood, makes some pertinent observations on the disease. He states that when diseased brood is placed above a strong, healthy colony, with a queen excluder between, so that any healthy brood may emerge,

¹ Reference is made by number in parenthesis to "Literature cited," p. 28.

the diseased larvæ are cleaned out as this is taking place. The union with a healthy colony and the strength gained by the emergence of so many young bees gives the colony the stimulus to eliminate the disease. He notes, as have many other beekeepers since, that in August, when the buckwheat honey flow begins, the stronger of the diseased colonies are stimulated to clean up.

Alexander (1) published a method of treatment for European foulbrood, the principle of which, after many varying failures and successes, is now the basis for the present method of treatment most used; that is, requeening with Italian stock. Alexander mentions the need of three factors: First, the necessity of requeening with young yellow Italians, as hybrids of Italian and black bees are prone to contract the disease in the first place and also are more likely to succumb to it; second, particularly emphasized, a period (at least 27 days, according to Alexander) of queenlessness in which to allow the bees properly to clean up the cells and polish them, preparatory for eggs of a new queen; third, a factor which is mentioned only casually but which is equally important with the other two, the direction to unite and strengthen diseased colonies before treating. So little emphasis was placed on this that the majority of beekeepers overlooked it in using Alexander's treatment and therefore condemned the treatment as unsuccessful except in rare cases.

In an editorial (8) in the same issue of the journal in which Mr. Alexander was writing, the question was raised as to why the period of broodlessness caused by winter, which is much longer than 27 days, does not always prevent a recurrence of the disease. Mr. Alexander answered this question by explaining that when the queen stops laying in the fall, the bees do not polish up the cells as they do earlier in the season, and that some of the dried-down material may remain until the next spring. The opinion also is given in this editorial that Italians are more able to resist the disease than hybrids because they do more thorough work in house cleaning and are less inclined to rob.

Phillips (6) makes the statement that "European foulbrood is more destructive during the spring and early summer than at other times, often entirely disappearing during the late summer and early autumn, or during a heavy honey flow," but gives no indication as to how this takes place. The same year Miller (2) published his theory of the relation of the nurse bees to the spread of European foulbrood. He believes that the nurse bees suck up the juices of a freshly diseased larva which has not become offensive, and then transmit the disease when feeding the healthy larvæ. On this supposition he believes that if egg laying ceases for 5 or 6 days ("the period the larvæ remain unsealed in their cells") there will no longer be larvæ in the proper condition for nurse bees to feed upon,

nor healthy unsealed larvæ to receive the infection, and the disease will thereby come to an end.

Dr. Miller has been using a 10-day period of queenlessness in his treatment of European foulbrood since his accidental discovery that 10 days were sufficient, but in a later article (3) in enlarging upon his nurse-bee theory he assumes that the larva is fed during a period of 5 days but is not effective as a carrier of infection during the whole time as probably no larvæ are torn open until they are 2 or 3 days old, thus making it possible to shorten the queenless period even more. He admits that not all the dead, partially dried larvæ will be cleaned out, but believes that it is only the fresh yellow ones which are infectious. He also states that nurse bees are not inclined to travel far on the combs, a fact which may explain why the disease may be found confined to one comb for several days before spreading farther. Dr. Miller seems to have overlooked several important factors which will be discussed later.

Quite an extensive piece of investigation was carried on during the summers of 1915 and 1916 by the author at the Massachusetts Agricultural Experiment Station upon the effect of requeening diseased colonies with various strains of Italian bees. At that time the importance of strong colonies with the requeening had not been emphasized so strongly and less attention was paid to that factor. The records show, however, that in a total of 50 colonies observed, covering two seasons, of 10 strong colonies only 2 showed recurrence, while 1 was doubtful; of 20 medium-strength colonies, 10 showed recurrence with 2 doubtful; of 14 weak colonies, 8 showed recurrence. In all these cases the new queen was not introduced until the colony was nearly or entirely clean. In the case of several of the weaker colonies it was necessary to strengthen them before requeening was possible, in order to save the colony. One or two of these, which were united and requeened with Italian stock, were the best colonies the next spring.

Adding some strength to at least part of Miller's theory is a statement in a letter by G. C. Matthews, formerly of this bureau, who wrote in February, 1918, concerning his observations in California in 1914. He found that where the hives stood in rows of pairs the disease continued to spread down each row to corresponding members of each pair. This ceased when he rearranged his apiary so that the rows of hives were at least 10 feet apart, and alternate pairs of hives were turned at right angles. No pair was allowed to remain close to another facing the same way. This prevented the drifting of nurse bees, which he believes to be the method of spreading the disease. Furthermore, he found by introducing one Italian queen into the middle colony of an isolated row of hybrid bees that there was considerable drifting of nurse bees. Seven days after the brood

from the Italian queen began to emerge, yellow bees were found on either side in several of the hybrid colonies. Speaking of uniting weak diseased colonies and requeening, Matthews writes:

After two or three were put together, each stack of brood was given an Italian cell. When young queens commenced to lay there was still disease in many of those hives, but as the queens increased in laying the bees cleaned out an ever-increasing sphere of comb for a brood nest until they had the hives free of disease. But in no case, however long a hive might be queenless, did I see the disease cleaned out before a virgin appeared in the hive. In other words, a virgin had to be present before the bees would commence their job of cleaning up. Therefore, I see little to commend the practice of keeping diseased colonies queenless 21 days.

A new bulletin by Phillips (7) has been issued recently by the Department of Agriculture. The fundamental idea emphasized is that "in keeping European foulbrood under control it is far more important to prevent the disease from getting a foothold in a colony than it is to eradicate the disease afterward." This bulletin, aside from discussing symptoms and methods of treatment, states concisely for the first time the facts observed in apiary practice on which successful treatment is based, and without an understanding of which it is difficult for a beekeeper to use preventive measures with any success.

The analysis of these factors of response in behavior to treatment, as stated by Phillips, has been used to some extent as a foundation for the present work on the behavior of the colony in relation to disease, in an endeavor to substantiate, with data obtained under controlled conditions, these facts that are constantly observed in apiary practice and, if possible, to eliminate confusion in methods of treatment.

PROCEDURE

Shortly after the middle of May, 1918, experiments were started in Ithaca, N. Y., at the Cornell Agricultural College. Through the kindness of Prof. J. G. Needham, head of the department of entomology, and others associated with him, the use of a small, isolated yard of bees and also of laboratory facilities was offered for the purpose of carrying on these investigations. This small apiary had been used previously in fruit-pollination studies and had no record of disease. The yard was admirably located in a naturally well-protected hollow beyond the college fruit orchards, about a mile and a half from the main college apiary or other apiaries, with high ground and woods intervening. The author and the Office of Bee-Culture Investigations are under deep obligations to the Cornell authorities for the assistance so cordially extended.

Being in the buckwheat district, the general locality was well adapted to the work because of the desire for as late a main honey

flow as possible in order not to have the influence of a heavy honey flow until other factors had been studied. At Ithaca the main honey flow is generally from buckwheat, coming from the 1st to the middle of August. Rather unfortunately for the best results from the experiments, however, the summer of 1918 was unusual in this section, for the abnormally heavy honey flow from clover necessitated finishing the work earlier than had been planned, owing to the great difficulty of artificially infecting colonies during the heavy honey flow.

There were seven colonies in the original experimental apiary. At first it was intended to work on a larger scale, but the trend of the observations soon led to the plan of working in more detail and on a smaller scale. These colonies were moved some distance apart to prevent drifting and robbing. Some were divided and some were strengthened in an effort to make a series of experiments on colonies of different strengths. The colonies were designated by letter and the combs of each colony by number. From time to time some of these colonies were artificially infected with diseased European foul-brood larvæ from samples sent to the laboratory for diagnosis. Similar colonies were held intact and uninfected for controls. The infection was made by feeding diseased larvæ macerated in sugar solution (about 50 per cent). For the preliminary experiments 10 larvæ were fed in about 250 c. c. of sirup. Later, after the heavy honey flow had begun, it was necessary greatly to increase this dose in order to start the infection. The infected sirup was fed to the bees in sterilized glass petri dishes, placed on top of the frames and protected by an empty comb-honey super placed on the regular hive-body with the cover on top.

At the time of inoculation, the condition of each colony was noted as to age, race, condition and appearance of the queen, proportion of nurse bees to old field bees, the number of frames of brood with the amount in each, its age, sealed or unsealed; in other words, the condition of the colony with regard to factors known to be significant in resisting disease. In two colonies the infected sirup was slightly colored with harmless eosin dye to determine where the fresh sirup was placed and its ultimate disposition. At first daily observations were made to determine the earliest appearance of disease, the period of incubation, the symptoms exhibited, and the rate of increase.

By holding up each comb in bright sunlight so that the light shone directly on the larvæ, it was easy to detect the first symptoms of the disease. All the healthy larvæ had the characteristic firm, well-rounded, pearly-white, glistening appearance. The first effect of the disease, besides an abnormal uneasy movement, was a loss of the

glistening character and a slight tinge of grayish or creamy discoloration which would not be noticed except in direct sunlight. These larvæ showed only *Bacillus pluton* present when examined microscopically, as will be mentioned later. Soon after these first symptoms, however, the more noticeable symptoms appeared, such as a larva with its back out, the increase of the light grayish yellow color, and, later, the moist, melting appearance.

A statistical record was kept of the number of larvæ showing new disease at each observation, the number previously diseased that had been cleaned out in the interval since the previous observation, and those remaining over in the cells uncleared for more than one period between observations. At various times observations were made of the behavior and types of bees engaged in cleaning up and the fate of the material removed. Great care was necessary in these observations to disturb the colony as little as possible. On good days it was sometimes possible to remove a comb carefully from the hive and to watch the bees continuing at their work, and even to watch the queen laying eggs. An eight-frame observation hive containing a strong healthy colony was given a diseased comb from time to time and the bees were observed as they worked on it.

One of the difficulties of the work was to find a satisfactory method of recording the desired data for each comb. At first the diseased cells were marked on the comb by a circle of red celloidin around the entrance of the cell. Although this dried rapidly, it proved unsatisfactory, as the bees, in their attempt to remove the foreign material, seemed to remove both diseased and healthy larvæ indiscriminately. Next small pins were used, inserted in the cell above the one showing disease. In this case the bees tore down the surrounding cells and completely removed the pins, many of which were found on the bottom board. Finally a method of plotting the diseased cells in a comb was adopted. An empty frame was laid off in inch squares by means of heavy black thread. This, used as a templet superimposed on a comb, aided in the location of the diseased and cleaned out cells, so that they could be recorded on a correspondingly ruled card (fig. 1). Placing this over the comb, it was easy to locate exactly each cell and to determine how long the diseased material remained, thus aiding in following the course of the disease throughout its various stages. The only difficulty with this method was the tediousness of the observations. Therefore, after the disease had become definitely established, daily observations of each colony were considered unnecessary. Longer periods showed just as well what was happening in the colony. Also, after the disease had developed enough so that it could be definitely predicted whether the colony would recover or gradually be exterminated, observations of behavior under treatment were

started, the method and degree of house cleaning being watched after the colony had been dequeened, strengthened, and requeened with good Italian stock. Note was also made of any recurrence of disease and

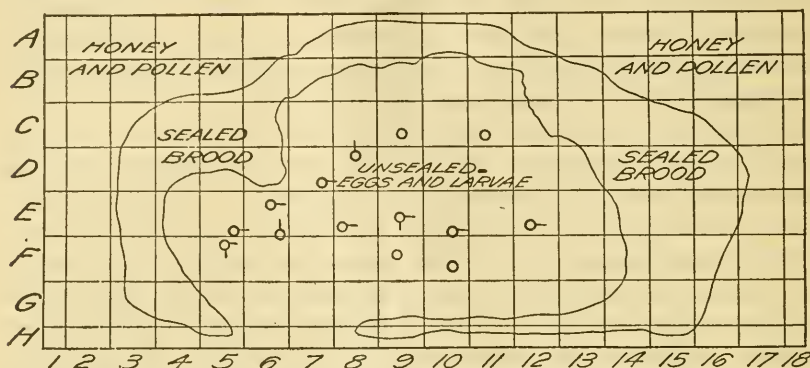


FIG. 1.—Method of plotting the location and history of diseased bee larvæ in the combs. ○ Freshly diseased larvæ. ○ Cells that have been cleaned out. ○ Cells that have been cleaned out and filled with nectar. ○ Larvæ remaining in the cells more than one observation period. The area of sealed brood was the amount present at the time of infection of the colony.

apparent reason therefor. In other words, a complete study was made of the cycle of the disease and of the activities of the bees during its course.

OBSERVATIONS

COLONY G

Race.—Hybrid.

Queen.—1917, dark and poor.

Bees.—Workers and drones very dark, almost black, very excitable.

Condition of colony at time of infection.—Brood in four frames, a little less than half sealed, besides two frames of eggs. Bees covering about eight frames, medium strength. Slightly more field bees than nurse bees, because of having divided this colony, old bees returning from the division.

Date of first infection.—May 28, 1918.

Material used.—Ten diseased larvæ from sample No. 5863, macerated in 250 c. c. of a 50 per cent sugar sirup.

First appearance of disease noted.—May 31, 1918, three days after inoculation.

Age of larvæ first attacked.—Three to four days after hatching from the eggs.

Colony G (fig. 2), hybrids, soon succumbed to the infection, the first diseased larva appearing three days after infection, the gross diagnosis being confirmed by the finding of *Bacillus pluton* on microscopic examination. The spread of the disease was rapid, the disease being present in only one comb on the third day and in seven combs on the seventh day. All of this early spread took place in brood unsealed

at the time of infection. The first high peak of the disease coming on the nineteenth day was followed by a slight improvement, when for a time the house cleaning exceeded the occurrence of fresh disease. This was probably due to the stimulus of the increasing honey

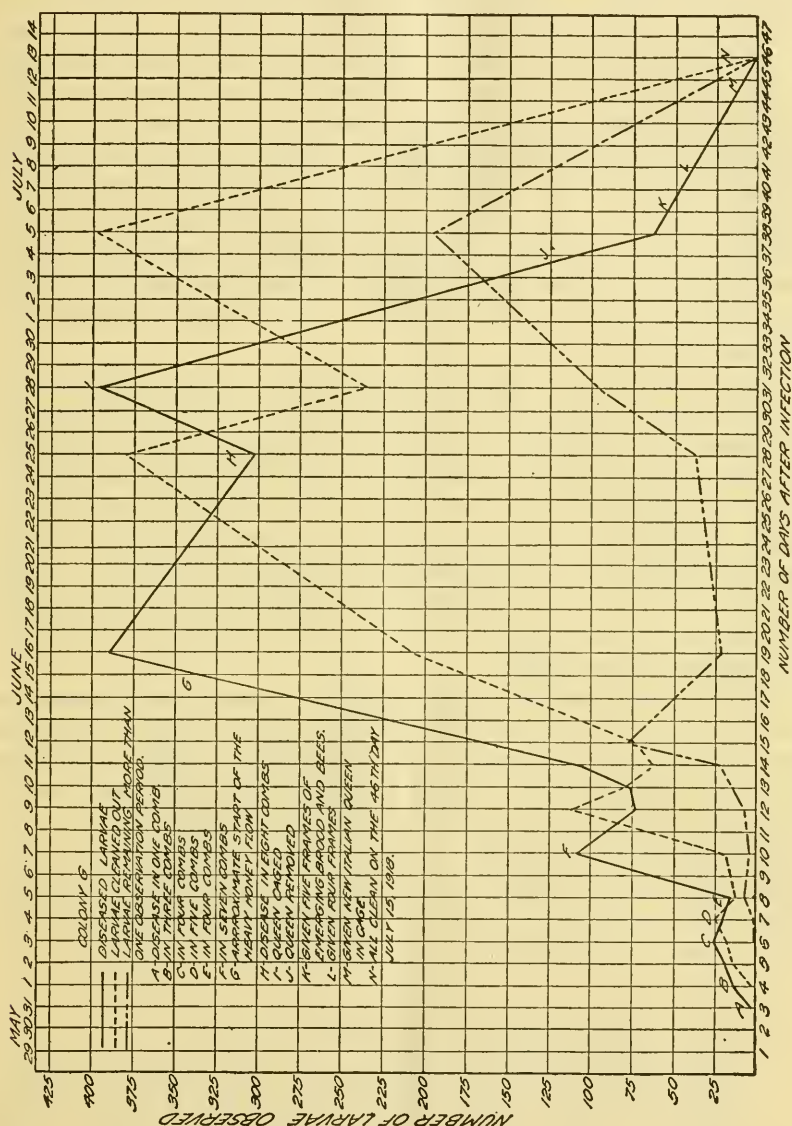


FIG. 2.—The course of European foulbrood in colony G.

flow. But as soon as the next series of eggs hatched, the disease again gained the upper hand, reaching another higher peak on the thirty-first day, at which time it was deemed necessary to start treatment. It had become evident that the colony was being overrun by the disease. More and more dead larvæ were being allowed to re-

main in the cells for several days without being cleaned out. Also more larvæ nearly ready for pupation were being affected. Most of these instead of remaining coiled were inclined to extend on the lower side wall in a brownish gray, slimy mass and exhibited a tendency to be viscid. At this stage of decomposition, when a stick is inserted the mass forms a coarse granular band for a short distance and then breaks so as to form droplike masses, but does not stretch out in a fine thread. These larval masses dried down to rubbery dark brown scales something like American foulbrood scales in appearance, but different in consistency. These scales could be removed quite easily and would bend like a piece of partially granular old rubber. They also lay irregularly placed in the cells, often spirally extended, while American foulbrood scales are uniformly on the lower side wall. The bacteriological explanation for this abnormal characteristic will be discussed later under bacteriological observations.

The predominance of these rubbery masses and scales increased as the disease progressed and the bees seemed to make little attempt to clean them out, even after the queen was caged on the thirty-first day, thus shutting off any increase of fresh larvæ, or even after the queen and all queen cells were removed on the thirty-seventh day. On the thirty-ninth and also on the forty-first day, five and four frames, respectively, of emerging brood and Italian bees were united with this colony, but it was not until a new Italian queen, confined in a cage, had been hung in on the forty-fifth day that a final complete cleaning up was made.

This new queen was not accepted, however, and a young queen was raised from the brood that was added to this colony, so that further observations were ended here although the virgin queen was killed and another Italian queen introduced. This colony was reported healthy, however, about the middle of August.

The hybrid bees seemed to lack ambition to fight the disease. When combs were removed from the colony, the bees never were observed to be working in the cells, and paid little attention to material partially drawn from the cells and crushed.

COLONY F

Race.—Italian, possibly with some slight hybrid blood.

Queen.—1917, fairly good condition.

Bees.—Workers, good color, fairly quiet, drones inclined to be darker.

Condition of colony at time of infection.—Brood in three frames, a little more than one-third sealed. Bees covering about six frames. Building up well. Proportion of field bees to nurse bees about equal.

Date of first infection.—May 31, 1918.

Material used.—Ten diseased larvæ from sample No. 5874, macerated in 250 c. c. of a 50 per cent sugar sirup.

First appearance of disease noted.—June 4, 1918, four days after infection.

Age of larvæ first attacked.—Four days after hatching from the egg.

Colony F (fig. 3), which was the next one to be infected, although not as strong as colony G, was of Italian stock and did not show the appearance of disease until one day later. On the fourth day one cell appeared in each of two combs. It was not until the twenty-

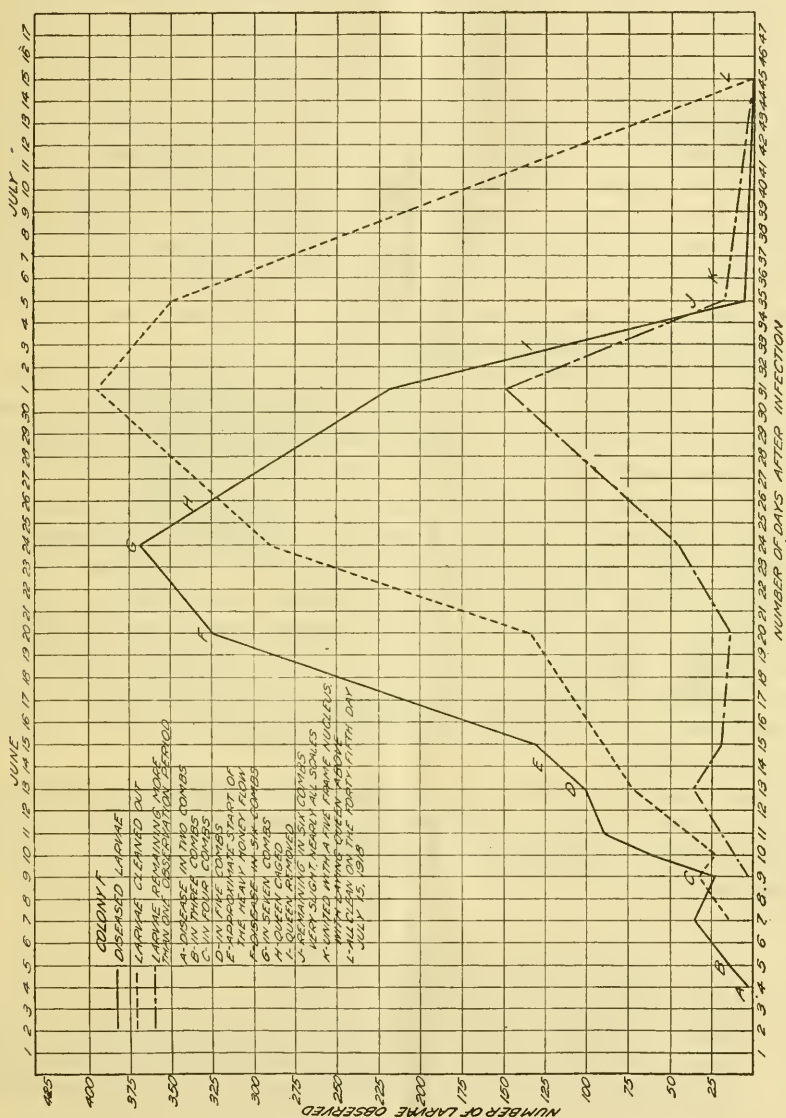


FIG. 3.—The course of European foulbrood in colony F.

fifth day that the disease had spread to seven combs, the total number of diseased larvæ being, as a whole, less than in the hybrid colony. There was not brood in all seven combs at the time of infection, but the brood increased faster than the disease spread. After the twenty-fourth day a permanent improvement began to be manifest.

This improvement continued after the queen was caged and became more marked after she was removed from the colony.

These bees were better house cleaners as well; the appearance of larvæ remaining over more than one observation period did not become evident until after the ninth day, compared with the sixth day in colony G. At no time were there as many of the larvæ nearly ready to pupate that were gummy or rubbery. Even though this colony was on the average weaker than colony G all the time, it handled the disease much better. It was 14 days before colony G had cleaned up to such an extent that it was deemed safe to introduce a new queen, while in colony F, with the Italian bees, the combs were so nearly cleaned of everything but a few old scales that a five-frame nucleus with a new Italian laying queen was united with this colony after a 10-day queenless period and in 9 days more everything was absolutely clean and the queen was laying in the combs that had had disease in them.

When an observation was made nine days after the new queen's eggs were first noted, it was found that there was a slight recurrence of disease in three of the combs. But, unfortunately, at the same time, queen cells and no eggs were found, denoting that for some reason this queen had not been accepted. Therefore the queen cells were all removed and a new queen was introduced. Although the author's observations ended of necessity soon thereafter, it was reported to him that this colony was doing nicely later in August and was perfectly healthy. If the first new queen had not disappeared, it is quite probable that as soon as a sufficient number of her bees had emerged they would have cleaned up the recurring disease in the same manner as was done in colony J, which will be mentioned later.

Several times in this colony, during the cleaning-up process, bees were watched in the act of sucking up juices of diseased larvæ that had been partially removed from the cells with the aid of forceps.

COLONY H

Race.—Hybrid, a division of Colony G, hybrid.

Queen.—1918. Of their own raising. Poor.

Bees.—Dark hybrids, almost black, excitable.

Condition of colony at time of infection.—Brood in three frames, a few eggs in one, only one small patch sealed, the remainder from eggs up to 4-day larvæ. Bees covering about five frames. Fairly good proportion of nurse bees.

Date of first infection.—July 1, 1918; second infection, July 8, 1918.

Material used.—20 old, dried, rubbery, diseased scales from sample No. 5898, macerated in 250 c. c. of a 50 per cent sugar sirup, colored with eosin.

First appearance of disease noted.—July 5, doubtful. Positive July 8, 7 days after infection.

Age of larvæ first attacked.—Four days after hatching from the egg.

Colony H (fig. 4) was treated as a double experiment. The infection of this colony was not started until after the honey flow had come on quite heavily. Also, instead of freshly diseased larvæ, old brown rubbery scales were used that showed *Bacillus pluton* present microscopically, but were heavily overgrown by *Bacillus alvei*. It was desired to learn whether these scales were still infectious, so that nurse bees working on them, cleaning them out, might get infective material on their feet and mouth parts which could be carried to healthy larvæ. This was noted later in the observation hive, where, under the magnifying glass, bees were seen trying to remove some of these rubbery scales, first moistening them with their tongues and then pulling at them with the mandibles and front feet.

This colony, which was marked hybrid and weak, was slow in developing the disease, partly because of the diluting effect of the

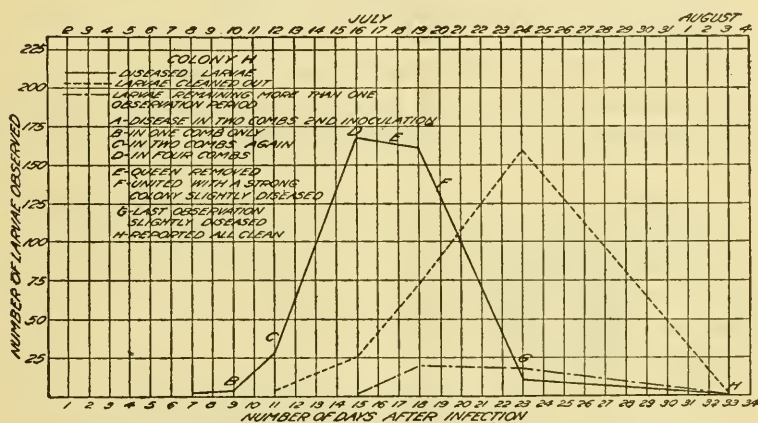


FIG. 4.—The course of European foulbrood in colony H.

heavy honey flow and probably partly because there was a smaller number of infectious organisms present in the scales than in fresh larvæ. This is explained by the fact that the secondary putrefactive invading organisms would tend to kill off the primary organism, because of the accumulation of the products of the putrefactive action.

On the seventh day before the disease was first noted, a second infection of scales macerated in sugar sirup was given this colony to counteract the effect of these retarding factors. However, later on the seventh day, diseased larvæ were found, and from then on the disease started to spread and increase irrespective of the heavy honey flow, exhibiting all the symptoms and tendencies shown in colony G, of which this colony was a division before infection.

On the seventeenth day it was necessary to remove the queen and start treatment, but what was taking place was evident. This removal of the queen did not seem to have a very marked effect on the house

cleaning until the colony was united with colony I, a slightly diseased Italian colony. They then began cleaning the H combs, and the combined colony was reported clean in August.

COLONY A

Race.—Italian with some possible slight hybrid blood.

Queen.—1918. Of their own raising.

Bees.—Workers, good color; fairly quiet. Drones, some slightly darker than pure Italians.

Condition of colony at time of infection.—Brood in seven frames about half sealed. Bees covering about nine frames with a good proportion of young nurse bees. Colony strong and building up.

Date of first infection.—July 2, 1918. Second infection, July 6, 1918.

Material used.—First, 20 diseased larvæ from sample No. 5937 macerated in 250 c. c. of a 50 per cent sirup, colored with eosin, abnormally heavy infection; second infection, 20 diseased larvæ from sample No. 5953 in 250 c. c. of uncolored sirup.

First appearance of disease noted.—July 8, 1918, in drone brood, six days after infection.

Age of larvæ first attacked.—Four days after hatching from the egg.

Colony A (fig. 5) was a fairly strong colony of Italians. Like colony H, it was infected after the heavy honey flow had started and was

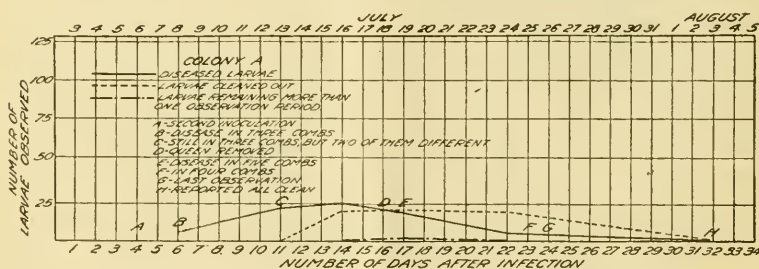


FIG. 5.—The course of European foulbrood in colony A.

given twice the amount of infective material colonies F and G received. Nothing having appeared on the fourth day, a second infection of the same amount was given. On the sixth day 6 diseased larvæ were seen in three combs. This colony, however, was so strong that the disease obtained very little foothold, and from the fourteenth day began to decline, or at least failed to make further gains. As a side experiment in this colony a comb of eggs laid by an Italian queen was placed in between two combs showing disease. If there is anything in the belief that Italian stock is more resistant to disease, the larvæ in this comb should not have developed the disease, or at least not so soon. However, on the sixth day one or two larvæ showed disease, increasing slightly in numbers for a few days until the observations were of necessity stopped. It was intended to perform this experiment with several variations, such as placing eggs laid by an Italian queen in a diseased hybrid colony and placing eggs from

a hybrid queen in a diseased Italian colony, but the presence of the heavy honey flow made it impracticable to carry the matter further.

This colony A cleaned up readily after removal of the queen and was reported all healthy in August. Although a new queen was given to them it is probable that a period of queenlessness and the returning of the same queen would have answered just as well.

COLONY I

Race.—Italian.

Queen.—1917, fairly good condition.

Condition of colony at time of infection.—Seven frames of emerging brood well covered with young bees. A strong 8-frame colony.

Date of first infection.—July 10, 1918.

Material used.—Thirty diseased larvæ from sample No. 5959, macerated in 250 c. c. of a 50 per cent sugar sirup. This was abnormally heavy infection of diseased material.

First appearance of disease noted.—July 15, 1918, five days after infection.

Age of larvæ first attacked.—Four days after hatching from the egg.

This colony was infected during the heavy honey flow, but although given a heavy infection it had sufficient strength, aided by the heavy honey flow, to prevent the disease from spreading. On July 15 there were a few diseased larvæ in two combs. On July 24, 14 days after inoculation, there were only a few diseased larvæ in three combs. This was after the queen had been removed on July 18 and the colony had been united with colony H on the 20th.

An interesting observation was that under the magnifying glass the methods of the nurse bees in sucking the juices from dead diseased larvæ and the pulling of the skins out to carry them away could be noted. No bee worked very long at a time on one larva. One after another worked until all was completed.

SUMMARY OF PREVIOUS EXPERIMENTS

Table I gives a partial summary of the data thus far described.

TABLE I.—*Showing the first appearance of disease noted after infection. Also the number of combs showing infection and the spread of the infection from comb to comb in the various colonies under observation*

Colony.	Date infected.	Days after infection.																											
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
		Number of combs.																											
1918																													
G ¹	May 28	..	1	3	..	4	5	4	..	7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	8
F ¹	May 31	..	..	2	3	..	..	..	4	..	..	..	5	..	..	..	..	..	..	..	6	..	..	..	7	..	..	..	..
H ²	July 1	..	..	..	..	..	2	..	1	..	2	..	..	..	4	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	July 8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
A ²	July 2	..	..	..	..	3	..	..	..	..	..	..	..	..	..	..	5	..	..	..	..	..	..	4	..	..	..	..	..
	July 6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
I ²	July 10	..	..	2	..	..	..	..	..	..	..	..	..	3	(Different from first two.)												..	..	..

¹ Experiments started before the beginning of the heavy honey flow.
² Experiments started after the beginning of the heavy honey flow.

In the first group, colonies G and F, it is quite apparent that the Italian bees, colony F, made the better showing, even though the hybrids were the stronger colony in the beginning. As may be seen from a comparison of the two plots in figures 2 and 3, in colony G wherever there was a lag in the house cleaning there was marked increase in the number of larvæ remaining over more than one observation period, and these increased until strengthening treatment was started. On the other hand, in colony F these were removed almost entirely by the time the strengthening treatment was started. The Italians did not allow the disease to appear as soon or to spread as rapidly, cleaned house better, left fewer larvæ to dry down to the brownish rubbery scales, and responded to the increased honey flow and treatment much more readily.

In the second group, colonies H, A, and I, the Italian colonies A and I again made the best showing. With the added diluting effect of the honey flow, they allowed the disease to gain no foothold whatever, while the hybrids, though aided by the honey flow, soon succumbed and allowed the disease to gain on them. It is evident that the Italian bees are much more vigorous house cleaners. In several instances, toward the end of the egg laying of the old queen, and well along in the progress of the disease, cells were noted on these diagrams which had previously contained diseased larvæ, but which had been cleaned out, and then in which disease had reappeared after other eggs had been laid and hatched in them. They were cells in which fresh nectar had not been placed between the two series of larvæ.

It was also noted that as the honey flow increased and as the brood became more scattered from the effects of the disease, more and more fresh nectar was placed in the brood nest in cells from which dead larvæ had been removed. Most of this nectar, however, was moved up later, particularly after the bees began preparing the brood nest for a new queen in the process of treatment. That the advent of a heavy honey flow was effective in controlling the disease is evident, particularly in the length of time between the infection and the first appearance of disease. The data, however, show little difference in the resistance to infection, or so-called immunity, being slightly in favor of the Italians, if there is any difference at all.

Disregarding the effect of the honey flow, the period of incubation of the disease is apparently between 3 and 4 days. However, it was noted that after *Bacillus pluton* was first observed it was anywhere from 24 to 48 hours before many characteristically diseased larvæ were observed. Therefore, the actual period of incubation is probably from 24 to 48 hours.

SUPPLEMENTARY OBSERVATIONS

STUDY OF NATURALLY INFECTED COLONIES

As a supplementary study to the preceding artificial infection experiments, some observations were made upon the behavior of naturally infected colonies undergoing treatment. Through the kindness of W. L. Bean, of McGraw, N. Y., it was possible to make a series of such observations. In his apiary of about 30 colonies, all hybrids, the majority were diseased when observed June 8, 1918. Soon thereafter Mr. Bean kindly loaned two of these diseased colonies to be carried to Ithaca for closer observation. Mr. Bean at once started treating his bees, requeening with Italian stock by the method of introducing a queen cell almost ready to emerge. Apparently, this method was successful, for in the latter part of July Mr. Bean reported all treated colonies healthy and some 800 pounds of surplus honey.

COLONY J

Race.—Hybrid.

Queen.—Queenless at time of arrival at Ithaca. Was poor hybrid of own raising, probably reared while disease was present in the colony.

Strength in spring.—Weak.

Strength at time of treatment.—Scattered brood in eight frames. Weak in bees, particularly in nurse bees.

Approximate date of disease first noted.—May 31, 1918.

Date of start of treatment observations.—June 16, 1918.

This colony made no effort to clean up, even though they had lost their queen shortly before being brought to Ithaca. On the 18th of June six frames of Italian bees and emerging brood were placed on top of it. At once house cleaning started, a reduction of 50 per cent being noted in the fresh, moist, melting larvæ within 24 hours. In this colony it was interesting to watch the bees doing the house cleaning, particularly when diseased larvæ in various stages of decomposition were partially withdrawn from the cell with a pair of forceps. With the aid of a powerful hand magnifying glass it was easy to watch them suck up the juices of the dead larvæ, even those which had decomposed to the extent of being a coffee brown in color and viscid in consistency. No bee would work long on a larva but would back off and wipe her tongue thoroughly with her front feet. It is conceivable that this might contaminate her, making possible carriage of the infection to the next larva fed, even though the juices of the diseased larva were not actually fed to the healthy one. The majority of bees engaged in this work were the Italians. From these and other observations of a similar nature there is no doubt that the contamination of the mouth parts is the primary method of spreading the disease inside the colony.

On June 25 an Italian queen was introduced in a cage with candy even though a few scales were still present. This was fully 10 days after the colony had lost its queen, if not a little longer. On June 27 the queen was out and laying in one comb. Eight days later, on July 5, a recurrence of disease was noted, one larva being discolored and sunken, showing *Bacillus pluton* on microscopic examination. From that time on, for about 20 days after the first eggs of this queen were noted, one or two new diseased larvæ appeared at each observation, the number decreasing, however, until about the twenty-sixth day when they had all disappeared. As the new young Italian bees increased, the disease decreased, until a point was reached where they were in the predominance and had eliminated the disease by their activity. This was also observed in colony F.

COLONY K

Race.—Hybrid.

Queen.—1917. Dark hybrid of their own raising, probably from diseased stock.

Strength in spring.—Weak.

Strength at time of treatment.—Eight frames of scattered brood and hardly enough bees to cover them.

Approximate date of disease first noted.—May 31, 1918.

Date of start of treatment observations.—June 20, 1918, at which time the queen was removed.

Colony K, when it was brought to Ithaca, was so weak that it would soon have died. The bees made no attempt to clean out larvæ that had been partially pulled out of the cells with forceps and crushed. On June 26, six days later, they were still showing freshly diseased, moist, melting larvæ from eggs laid by the old queen, just before removal. At this time five frames of emerging brood and Italian bees were given this colony. On the 27th a new Italian queen was hung in with the cage closed. The presence of the new queen, however, seemed to give added impetus to the house cleaning so that by July 1, 11 days after removal of the queen, they were practically cleaned up and the cage was opened with candy in the opening. Further observations on this colony were ended because they refused to accept this queen. By the time another queen finally was accepted and was laying on July 18, it was too late, as the season's work was closed by the 23d.

BEHAVIOR OF BEES IN CLEANING CONTAMINATED CELLS

On June 6, 1918, a sample was received for diagnosis (No. 5898), consisting of an entire brood comb, containing quite an area of capped honey. About one-half of each side of the comb contained a large number of dead and diseased European foulbrood larvæ, in stages varying from the yellowish, moist, melting larvæ to dried rubbery scales of which there was quite a large proportion. This was

the same sample from which infectious dried scales were used to infect colony H. After this comb had remained in the laboratory, wrapped in paper for about 3 weeks, it was placed in the strong colony in the observation hive. The frame was first placed in the middle of the hive for about an hour and was then removed to the outside, where the work of the bees on it could be watched. A large number of what appeared to be young nurse bees were already hard at work on the dried diseased material. The bees, working on the dried gummy masses, would wet the mass with their tongues for a while and then tear at them with their mandibles, at times removing pieces large enough to be seen from the outside. Often these small pieces were apparently dropped to the bottom board. No one bee worked long at one place. Those bees working particularly on the fresh, moist material, when leaving, would carefully wipe their tongues with their front feet, thereby transferring some of the infection to them. Other bees were at work carrying away the larger, more easily removable dead masses. The entrance also was watched to see if any of this material was carried out. Several bees were observed carrying out portions of dead larvæ or pupæ. One bee carried a piece about 2 yards before dropping it. Others dropped what they were carrying soon after leaving the entrance, but on examining the surface of the ground about the entrance, very little material could be distinguished, so that apparently most of the material removed must have been carried some little distance before being dropped. After about an hour's work it was apparent that considerable progress had been made. This comb was removed before it was entirely cleaned and later placed in another healthy colony for observation. It was quickly cleaned up and quite a bit of nectar placed in it and, eventually, several square inches of brood. Observations, however, had to be stopped before any appearance of recurrence was noted. This same observation hive was given one or two other diseased combs to clean, but with the repeated probable infection from these sources the colony was so strong that no disease was noted in it during the entire season of observations.

POSSIBLE INFECTION THROUGH QUEEN

Colony M was a small nucleus made to receive the old queen from diseased colony K from McGraw, N. Y. The queen was introduced on June 20, 1918. For a while she laid fairly well, it being necessary to add one or two more combs. But later her brood became more and more scattered. Finally, on July 8, there was observed one dead larva, which looked suspicious, but which, on microscopic examination, proved to be negative. On July 10, however, one definite cell appeared and several other slightly yellowish, abnormally colored larvæ. This dead larva contained *Bacillus pluton*. From then on until this queen was killed and the colony united with another dis-

eased colony, more discolored larvæ appeared, showing definitely the development of the disease. As far as could be seen the only source of infection was the queen which had come from a diseased colony.

This occurrence had been observed previously by the author while employed at the Massachusetts Agricultural Experiment Station. During the summer of 1916 eight queens taken from diseased European foulbrood colonies were introduced into isolated, healthy nucleus colonies. Of these eight nuclei three developed European foulbrood, two were doubtful, and three remained healthy. Several such instances have been mentioned in the literature of beekeeping.

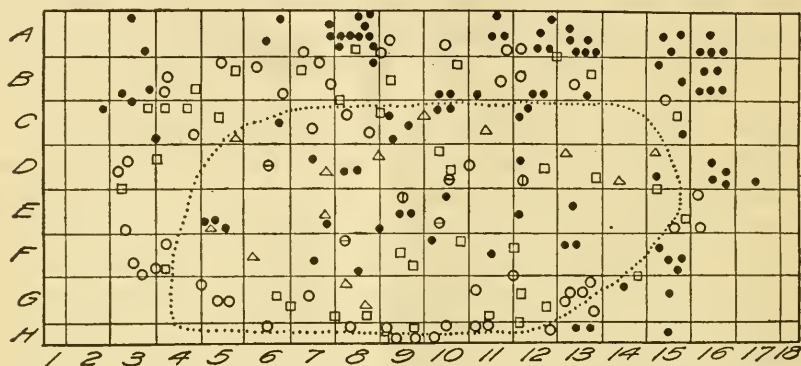


FIG. 6.—Distribution of cells containing infected sugar sirup and subsequent spread of the disease in a comb taken from colony H. Area covered by brood at time of infection, mostly unsealed. • Location of cells containing infected colored sugar sirup on July 3, 1918. ⊙ First positive diseased larvæ noted, 2 on July 8. ⊗ Number of new diseased larvæ (4) on July 10. Δ Number of diseased larvæ (13) on July 12. □ Number of diseased larvæ (39) on July 16. ○ Number of diseased larvæ (52) on July 19.

DISTRIBUTION OF INTRODUCED INFECTED MATERIAL

An interesting experiment was carried out with sugar sirup, colored by a small amount of a harmless anilin dye, eosin, used as an indicator, which gave to the sirup a bright red color. The object of this experiment was to determine where the sirup, or, more important, where fresh nectar is first placed in the hive and combs. On May 27 two colonies were fed this colored sirup from above some time before the heavy honey flow from clover started. The results were striking, for in nearly every case the colored sirup was easily discernible in the cells and the greatest part of the sirup was located in quite a definite area. These colored cells were either scattered among the cells containing the larvæ or were placed in a ring of cells adjacent to the brood area toward the top of the comb, little being placed with the solid stores (fig. 6). Furthermore, for nearly 36 hours after the feeding practically all the young nurse bees showed a marked pinkish discoloration of the anterior end of their abdomens, denoting the dis-

tention of the honey stomachs by the retention of the colored sirup therein. About half the bees in the hives were discolored in this manner. After a day or so, however, this began to disappear. Also the number of cells showing the pink discoloration began to disappear. Evidently the sirup had been moved up, worked over, and mixed with other nectar or consumed.

Later, some time after the heavy honey flow had started, shortly after July 1, two more colonies were fed colored sirup, this time infected with diseased larvæ macerated therein.

In these cases the discolored abdomens were noted about as before, but the colored cells were less numerous and the color less striking. The location of the colored cells was similar to that in the former experiment; that is, mainly in the brood area or just contiguous to it and mostly above. The outside combs, containing considerable honey, showed scarcely any of the colored cells. This time these colored cells disappeared sooner, showing that the infected material must have been much diluted quite soon after being taken up from the feeding dishes.

Figure 6 shows the method of plotting the location of diseased larvæ in the combs and also the location of the cells containing the colored sugar sirup. As will be noted, a fairly large proportion of these cells are located within the area of brood at the time of feeding. It is interesting to note the tendency of diseased brood to form concentric circles, showing the two series of larvæ occurring between the dates noted. The spreading was from two cells at first to quite a large number at the last observation shown.

AGE AT WHICH LARVÆ ARE INFECTED

In previous observations it was constantly noted that the larvæ affected by European foulbrood were regularly at least 4 days old, the age at which the coiled larvæ completely fill the bottom of the cells. Occasionally a slightly younger and smaller larva would become diseased, but this was not the common occurrence. Furthermore, in the cases where the colored sirup was fed the bees, within 24 to 36 hours quite a number of larvæ averaging 4 days old could be seen discolored from having been fed this sirup, while it was noticeable that the younger larvæ under 3 days old never showed the discoloration. These colored larvæ were examined in a smear under a microscope, but the infecting organisms, being comparatively few in number, had not increased sufficiently at that time to be apparent.

The question now arises as to the age at which the larvæ first are fed nectar or infected material. There has been much controversy over the subject of composition and source of the larval food, but as yet no conclusive scientific evidence has been presented. Irrespective of the question whether the food at various stages originates from glands or is regurgitated, it is apparent from these observations that

there must be a difference between the food which larvæ younger than approximately 3 days old receive and that fed to older ones. Otherwise the younger larvæ would also show the pink coloration. Von Planta (9) by chemical analyses, of questionable exactness, however, makes a division in the feeding of the larvæ at the age of 4 days, at which time the high protein and low sugar content change to lower protein and higher sugar content. These analyses would tend to coincide with the above observations, only it is probable that the change begins earlier.

Additional data upon this subject are recorded in Tables II and III, although the observations were primarily for another purpose. In order to obtain further information relating to a possible difference in resistance to disease between Italian and hybrid bees, a careful record was made of the time when eggs were first noted in empty combs after the infection of the colony and when larvæ first showed disease thereafter. In the case of comb Special No. 2, the eggs were laid by an Italian queen in a healthy colony and then placed in a diseased colony. Colonies F, A, and I were of Italian stock while colonies G, H, and J were hybrid. In the recurrence of disease all were given new Italian queens. As has been mentioned before, as soon as the bees of the new Italian queens emerged in sufficient numbers the disease disappeared.

TABLE II

THE FIRST APPEARANCE OF DISEASE IN COMBS IN WHICH EGGS WERE LAID AFTER THE COLONY WAS INFECTED

Colony and comb No.	Number of days after eggs were first noted in comb.													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
G 4.....										×				
G 6.....						×	×							
G 7.....							×							
G 8.....							×							
F 3.....							×							
F 4.....								×						
F 7.....						×								
H 3.....									×					
H 5.....									×					
A 2.....											×			
A 4.....											×			
A 5.....						×								
A 7.....								×						
A 8.....											×			
Spec. 2.....						×								
I 3.....									×					

RECURRENCE OF DISEASE AFTER EGGS OF A NEW QUEEN WERE FIRST NOTED IN THE COMBS

J 2.....														×
J 3.....														×
J 4.....							×							
J 5.....								×						
J 6a.....							×							
J 6b.....														
J 7.....										×	×			
J 8.....							×							
F 3.....									×					
F 4.....									×					
F 7.....									×					

TABLE III.—Average time, under various conditions, in which disease becomes apparent in a colony after infection with European foulbrood. (Averages taken from Table II)

	Before the heavy honey flow.
	Days.
Colony G, hybrid.....	7½
Colony F, Italian.....	7
Average of these two.....	7½
	During the heavy honey flow.
	Days.
Colony H, hybrid.....	9
Colony A, Italian.....	8½
Colony I, Italian.....	9
Average of these three.....	8½
	Recurrence of disease, after treatment, during honey flow.
	Days.
Colony J, hybrid originally.....	9¾
Colony F, Italian originally.....	9
Average of these two.....	9½

The data shown, particularly in Table III, tend to disprove the theory that Italian bees have a natural immunity or resistance. If a larger number of observations could have been made, the variation would have appeared less. The effect of the honey flow is evident, however.

When it is a question of the age at which the larvæ are fed material that contains infection, these figures are significant. In the life history of the bee, 3 days are spent in the egg and from 5 to 6 days as larva before capping, making a period of 9 days in all. After 3 days in the egg and after having been fed predigested food for 3 days, with the additional 24 to 48 hour period of incubation, as was observed earlier in this paper, the larva ought to show disease from the fourth to the fifth day after hatching, or the seventh to eighth day of its existence, if Von Planta's assumption is correct. From actual observation this was found to be true and from observation of the averages in Table III it is seen that the first appearance of disease occurs between the seventh and ninth days, varying with the conditions of the honey flow.

Referring to Dr. Miller's theories, it is hard to believe that there is not plenty of highly infectious material left in the colony after a 5 or 6 day period of queenlessness. Aside from actual observations of moist, yellow, melting larvæ present more than 6 days after the

queen has been removed, the juices of which the workers sucked up with avidity, the final eggs laid will be just at the stage where the disease first appears; that is, 3 to 4 days after hatching, at the end of a 6-day period. Furthermore, even though the nurse bees do not feed to healthy larvæ the material that is taken up in cleaning out the cells in varying stages of decomposition, infection, even from scales, may be carried on the feet, mouth parts, and tongue, particularly, as was definitely shown with colony H, since these scales are infectious. The period of queenlessness and the consequent house cleaning are absolutely dependent on the strength of the colony. A strong colony cleans up rapidly, particularly after the introduction of the new queen in a cage plugged with candy. A weak colony, on the other hand, has not sufficient bees to clean even after complete introduction of a queen, and the disease soon appears again. Under average conditions, therefore, it would appear unsafe to allow less than a 10-day period of queenlessness in treatment of European foulbrood.

MICROSCOPICAL BACTERIOLOGICAL OBSERVATIONS

A large number of microscopic examinations were made of larvæ under various conditions for the positive presence of the characteristic groups of *Bacillus pluton*. These examinations were made mainly as a check on the gross observations of the first appearance of the disease. Cover glass smears were made of crushed larvæ, stained with carbol fuchsin and mounted in Canada balsam. These examinations were made at regular intervals after the colonies were infected, larvæ of all ages being examined.

It was found in the smears of those larvæ showing the first slightly abnormal symptoms that *Bacillus pluton* was the only organism present. This substantiates White's (12) observations that before the disease could be detected by gross examination, by a histological study of sections of larvæ during the period of incubation it was demonstrated that "in the production of the disease *Bacillus pluton* was the first invader of the healthy larvæ."

As the disease advanced in the various colonies, observations were made of larvæ in various stages of decomposition. The bacterial content was found to vary with the change of appearance of the larvæ during decomposition. The presence of these secondary invaders easily explains the atypical appearance of certain types of European foulbrood that heretofore have been very confusing to the bee-keeper.

For a short time after the death of the larva, the color remains a moist, creamy-grayish yellow. This is during the period when *Bacillus pluton* and such occasional secondary invaders as *Streptococcus apis* or *Bacterium eurydice* and other organisms, which do not form

spores, are predominant as described by White (12) and McCray (4). Soon the putrefactive spore-forming organisms increase in number, *Bacillus alvei*¹ being the one most commonly found. This is seen particularly in the case of the more mature larvæ, which when dying extend more or less irregularly in the cells, becoming the grayish brown slimy masses which develop into the dark brown granular rubbery scales. This fact has been observed for a long time in the many samples which have been received for diagnosis. A partial description of these scales and of the presence of *Bacillus alvei* in them is given by McCray and White (5), but the experimental observations described in this paper added to diagnostic observations show that this condition is generally much more pronounced and common than described by these writers from laboratory observations. The rapid increase and peculiar process of decomposition of *Bacillus alvei*, after the death of the larva, often to the exclusion of all other organisms, accounts for this abnormal appearance. In the case of American foulbrood, almost never is any other organism found associated with the disease but *Bacillus larvæ*, the cause of the disease. This accounts for the constancy of the symptoms as compared with the variation of symptoms in European foulbrood where there may be several secondary invaders.

Furthermore, in making the smears of the diseased larvæ upon cover glasses, the peculiar whitish saclike extrusion of the larval intestines was often noticed on crushing the larvæ preparatory to smearing, which White (10) describes as a gross diagnostic character. When this sac was removed and smeared separately, it was always found to be heavily loaded with *Bacillus pluton*. Therefore it is safe to assume that the intestinal tract is the primary focus of infection, while the secondary putrefaction takes place mostly in the body tissues of the dead larva.

Coincident with the microscopic examination of larvæ, several examinations were made of the contents of the ventriculus, rectum, and in a few cases of the honey stomach and mouth parts of bees. These bees were presumably nurse bees taken from diseased combs, some in the very act of sucking up the juices of dead diseased larvæ. Although insufficient observations were made to give conclusive evidence, some interesting information was obtained.

As may be seen from Table IV, the number of cases where *Bacillus pluton* or other organisms associated with infectious material were found in the intestinal contents is not very large. However, of more

¹ *Bacillus alvei* originally was supposed to be the primary cause of European foulbrood, but has been proved by White and others to be only a common secondary invader. *Bacillus alvei* has purely putrefactive functions. From its cultural and biochemical characteristics, *Bacillus alvei* apparently belongs to the common *Bacillus subtilis* (hay bacillus) group of spore-forming organisms, all having mainly putrefactive functions.

importance probably, *Bacillus pluton* was found in a smear made from the mouth parts of a nurse bee and also in the contents of the honey stomach of another. If these observations had been carried out systematically, instead of only casually, it is expected that much more positive data might have been obtained along these lines, owing to what is known already of the habits of house-cleaning bees working on diseased material.

TABLE IV.—The results of the microscopic bacterial examination of the contents of the intestinal tracts of nurse bees taken from diseased colonies

Microscopic findings.	G.	F.	H.	A.	I.	J.	K.	Total.
Positive <i>Bacillus pluton</i>	1	2	2	.....	.....	.....	4	9
Negative <i>Bacillus pluton</i>	11	24	18	17	12	6	9	97
<i>Bacillus alvei</i> or doubtful <i>Bacillus pluton</i>.....	.....	3	1	.....	.....	7	.....	11

SUMMARY AND CONCLUSIONS

In arriving at the following conclusions an effort has been made to state them in a manner which will indicate the substantiation of previous observations made both in the laboratory and in the apiary. It may be noted that many of these conclusions are similar to some of the statements made in Farmers' Bulletin 975 in the summary of facts which apiary practice has brought out.

1. European foulbrood is an infectious disease. *Bacillus pluton* was found to be the primary invader, appearing in the intestinal tract of larvæ before death, contemporary with the first slightly apparent symptoms.

2. The variation in the appearance of the diseased larvæ after death is due to the presence or absence of secondary invaders.

3. The period of incubation for European foulbrood was found to be from 36 to 48 hours, although the gross symptoms usually do not become apparent in less than 3 or 4 days, varying with conditions of honey flow and strength of colony.

4. It has been noted in apiary practice that the first brood of the year usually escapes with little loss. During the first 5 to 7 days the spread of the disease in the colony after infection is slow, after which the increase is rapid under favorable conditions. The critical time, therefore, to detect the disease and start treatment is early in its course, thus making conditions unfavorable.

5. The evidence tends to confirm the theory that one of the ways the disease is spread in the colony is by the house-cleaning bees, and from colony to colony by their drifting. It is quite probable that the infective organisms are carried on the mouth parts and pedal appendages. The question of infection from intestinal contents or from

the source of larval food at various stages needs further substantiation.

6. Irrespective of strength of colony, the Italian bees were found to resist infection much better than hybrids and showed more ability to overcome the disease.

7. This apparent resistance of the Italian bees was observed to be largely due to the more vigorous house-cleaning characteristics rather than to a natural resistance or immunity to the disease. There was very little difference in the apparent period of incubation between the Italian and hybrid colonies, possibly a slight difference in favor of the Italians. Furthermore, it was noted that often there may be a slight recurrence of disease in the brood of the new Italian queen until a sufficient number of her bees have emerged to eliminate the infection by house cleaning. Apparently, infection is not always entirely removed by a period of queenlessness.

8. As a rule, requeening is necessary in the treatment of European foulbrood, except possibly in the strongest Italian colonies, which show only slight infection. Where a considerable quantity of disease is present, sufficient to require treatment, it was found unsafe to use a period of less than 10 days' queenlessness, due to the infectious condition of the diseased material remaining and the accompanying behavior of the colony.

9. The stronger the colony in Italian bees, the more rapid was the recovery.

10. A heavy honey flow tends to prevent infection from gaining a foothold. It also tends to eliminate the disease if present before the start of the heavy honey flow. This was found to be due to the effect of dilution on the infection because of the influx and direct feeding of the fresh nectar to the larvæ.

11. European foulbrood is a disease of weak colonies. It was found to be difficult effectually to infect any but the very weak colonies during the heavy honey flow. Therefore, colonies kept strong up to the time of the honey flow run very little danger of contracting European foulbrood. This and others of the facts observed are in exact harmony with facts already observed in apiary practice.

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¹ "Black brood" is an old name for European foulbrood.

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TWO LEAFHOPPERS INJURIOUS TO
APPLE NURSERY STOCK

By

A. J. ACKERMAN, Scientific Assistant
Deciduous Fruit Insect Investigations

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TWO LEAFHOPPERS INJURIOUS TO APPLE
NURSERY STOCK.

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INTRODUCTION.

Serious injury to apple nursery stock due to the attack of leafhoppers attracted the writer's attention while engaged in the investigation of nursery fruit insects at West Chester, Pa. An examination of the injury showed the presence of two species of leafhoppers, the common apple leafhopper¹ and the rose leafhopper.² Further study proved that each species produced a distinct type of injury, that caused by the apple leafhopper being by far the more serious. The conflicting nature of the entomological literature regarding the character of injury caused by these two species and their habits led the writer, under the direction of Dr. A. L. Quaintance, of the Bureau of Entomology, to undertake a study of their individual life histories and the means for their control.

¹ *Empoasca mali* (Le Baron); order Hemiptera, suborder Homoptera, family Cicadellidae.

² *Empoa rosae* (Linn.); order Hemiptera, suborder Homoptera, family Cicadellidae.

The destructiveness, habits, food plants, and life history of each species are treated separately herein. A detailed account of the experimental work carried out for the control of these two species together with the most efficient remedy is included.

The data on biology and control were obtained at West Chester, Pa., during the seasons of 1915 and 1916, supplemented by field observations at several points in southeastern Pennsylvania, and western Maryland.

THE APPLE LEAFHOPPER, *Empoasca mali* (Le Baron).

HISTORY.

This species was originally described by Le Baron (1) in 1853¹ under the name *Tettigonia mali*, and it was recorded by him as injurious to fruit trees in Illinois. In 1862 the genus *Empoasca* was erected by Walsh (2) with a description of three new species, but no mention was made of *mali*. Carlos Berg (3, p. 273), in 1879, described a leafhopper from Argentina as *Typhlocyba phytophila*, and this name later was considered by Gillette to be a synonym of *Empoasca mali*. In 1883 Forbes (4) sent specimens of a green apple leafhopper to Uhler who determined them as belonging to the genus *Empoa*; subsequently these insects were described by Forbes (5) as a new species, *Empoa albopicta*. Woodworth (6) transferred *Empoa albopicta* Forbes to the genus *Empoasca* in 1889 and called it *Empoasca albopicta*. The first reference to this species under its correct name, *Empoasca mali*, was made by Gillette (7) in 1890. Osborn (8) and later Gibson (17) mentioned it as injurious to potatoes, and Gillette (9), in 1898, gave the food plants and distribution.

Frequent references to this insect have been made in American entomological literature under the name of "the apple leafhopper" and "the currant leafhopper," by Britton (12), Brues (13), and Garman (16) among others. It has been often referred to as the most injurious leafhopper, both to apple and to various field crops. Washburn (15), in 1908, was the first writer to treat of this insect at any length. He published a record of the seasonal history, food plants, injury, and control of the apple leafhopper as a nursery pest in Minnesota. In 1910 R. L. Webster (18) made a detailed study of the life history and control of this insect on apple nursery stock in Iowa. In 1915 Webster (20) published an account of *Empoasca mali*, treating it as a pest of potatoes.

DISTRIBUTION.

There are no records showing that the apple leafhopper occurs in Europe. In America, outside of the United States, it has been reported from Okanagan, British Columbia, from Nova Scotia, several

¹ Figures in parentheses refer to "Literature cited," p. 34.

points in the Province of Ontario, from Mexico, Porto Rico, and Corrientes, Argentina. In the United States this species is widely disseminated, doubtless due to the variety and abundance of its host plants. From specimens in the collection of the United States National Museum, and from the collection, correspondence, and notes of the Bureau of Entomology, it appears to be present in almost every State in the Union.

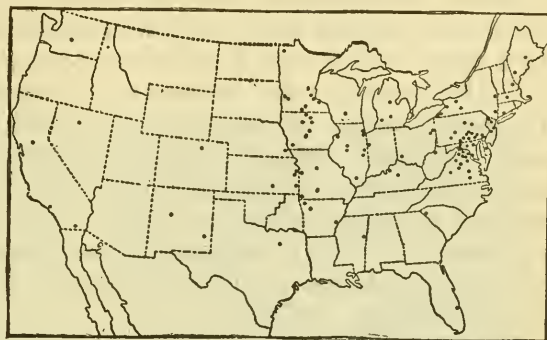


FIG. 1.—Distribution of the apple leafhopper (*Empoasca mali*) in the United States.

(See fig. 1.) It is found in greatest abundance throughout the eastern humid area of the Upper Austral Zone.

FOOD PLANTS.

The food plants of *Empoasca mali* (Le B.) are very numerous and varied. In nurseries this insect prefers apple but it also feeds in great abundance on Norway maple and various oaks. Among field crops it is partial to alfalfa, clover, potato, and beets, in about the order named.

A list of all host plants reported, upon the majority of which the writer has noted this insect feeding, follows:

<i>Acer negundo</i> , box-elder.	<i>Prunus pissardi</i> , purple-leaved plum.
<i>Acer platanoides</i> , Norway maple.	<i>Prunus</i> spp., cherries and plums.
<i>Althea rosea</i> , hollyhock	<i>Pyrus baccata</i> , Siberian crab.
<i>Amygdalus persica</i> , peach.	<i>Pyrus communis</i> , pear.
<i>Apium graveolens</i> , celery.	<i>Pyrus malus</i> , apple.
<i>Avena sativa</i> , oats.	<i>Quercus</i> spp., oaks.
<i>Beta vulgaris</i> , beets.	<i>Rheum rhaponticum</i> , rhubarb.
<i>Betula</i> sp., birch.	<i>Rhus cotinus</i> , smoke-tree.
<i>Cannabis sativa</i> , hemp.	<i>Ribes oxycanthoides</i> , gooseberry.
<i>Castanea</i> sp., chestnut.	<i>Ribes rubrum</i> , currant.
<i>Corylus americana</i> , hazelnut.	<i>Rubus</i> spp., blackberry and raspberry.
<i>Crataegus</i> sp., hawthorn.	<i>Rosa</i> spp., roses.
<i>Cydonia oblonga</i> , quince.	<i>Secale cereale</i> , rye.
<i>Dahlia</i> sp., dahlia.	<i>Solanum tuberosum</i> , potato.
Gramineae, grasses.	<i>Sorbus americana</i> , mountain ash.
<i>Hamamelis virginiana</i> , witch-hazel.	<i>Sorghum</i> sp., sorghum.
<i>Hicoria pecan</i> , pecan.	<i>Syringa</i> sp., lilac.
<i>Juglans nigra</i> , black walnut.	<i>Tilia americana</i> , American linden.
<i>Juglans</i> sp., walnut.	<i>Trifolium</i> sp., clover.
<i>Medicago sativa</i> , alfalfa.	<i>Ulmus americana</i> , American elm.
<i>Phaseolus vulgaris</i> , beans.	<i>Viburnum</i> sp., snowball.
<i>Populus</i> sp., poplar.	<i>Vitis</i> spp., grapes.
<i>Prunus virginiana</i> , choke-cherry.	<i>Zea</i> sp., corn.

CHARACTER OF INJURY.

The injury caused by the apple leafhopper to nursery apple trees is due to the feeding of the nymphs and adults on the underside of the tender terminal leaves from which they extract the plant juices. As a result of this attack the leaves become undersized and curled (Pl. I, B), causing a decided check to the growth of the new wood. The curling begins at the apex and extends toward the base of the leaves, the lower surface always being rolled in. This type of injury differs from aphid leaf-curl in that aphids roll the leaves more tightly and curl them from the sides instead of from the tips. During the progress of the injury produced by *Empoasca mali* the leaves become wrinkled and the loss of sap finally causes the tips to dry up and turn brown. (See Pl. II, fig. 2.)

The nymphs, because of their greater numbers and due to the fact that they spend the entire nymphal period on a few leaves only, cause more serious injury than do the adults. The latter feed only for a short time, being principally engaged in egg-laying, and during this period they fly from one tree to another. Injury by the feeding of the adults, therefore, is of little importance when compared with the localized injury produced by the nymphs. Consequently, the stunted terminal growth is most apparent at the time when the nymphs are most abundant on the foliage. As the nymphs gradually disappear the terminal shoots seem to revive and develop normal leaves above the stunted ones. (See Pl. I, A.) At the time of infestation by the next brood of nymphs, however, a similar check to the new terminal growth is produced. Thus retardation in growth occurs periodically throughout the season corresponding to the periods of infestation by the successive nymphal broods, while intervening between each infestation there is a short period during which the terminals maintain a normal growth. Although the different broods of nymphs overlap slightly the successive checks in terminal growth usually are well defined.

In the vicinity of West Chester, Pa., there are three broods during the season and three corresponding checks in the terminal growth. The first growth-check takes place during the latter part of June when the first nymphal brood is feeding; a second and a third check appear during the latter part of July and August, respectively, at the time when the second and third broods of nymphs are most active on the foliage. The first brood is the most abundant on apple and consequently causes more injury than do either of the two following broods. Adults of the first brood do not confine their activities to apple alone, as many scatter to other host plants to feed and oviposit.



THE APPLE LEAFHOPPER (*EMPOASCA MALI*).

A, Terminal leaves of apple shoot outgrowing injury by the leafhopper; *B*, curled condition of terminal leaves caused by the leafhopper.

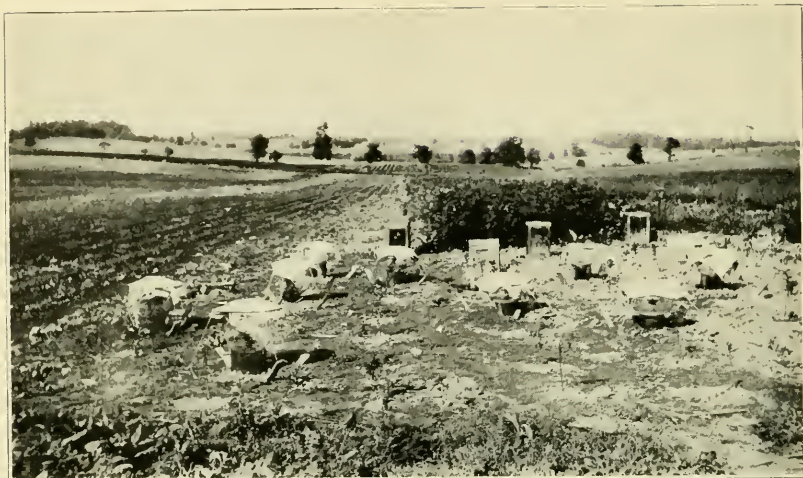


FIG. 1.—CAGES USED FOR REARING THE APPLE LEAFHOPPER IN NURSERY,
WEST CHESTER, PA.

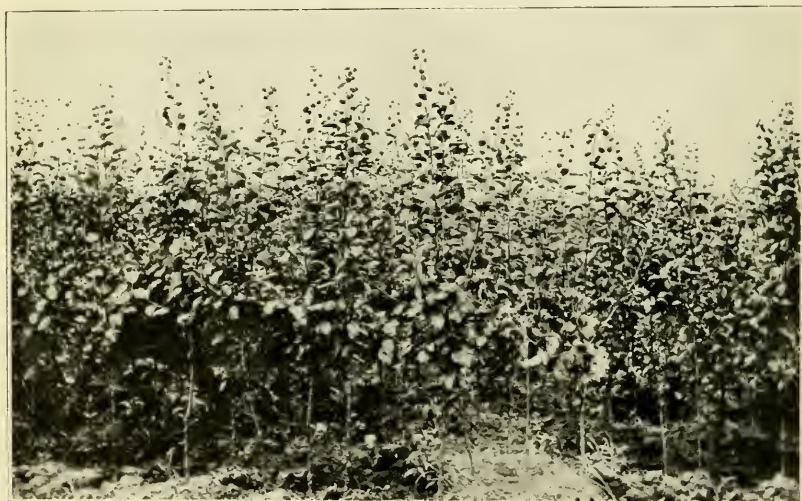
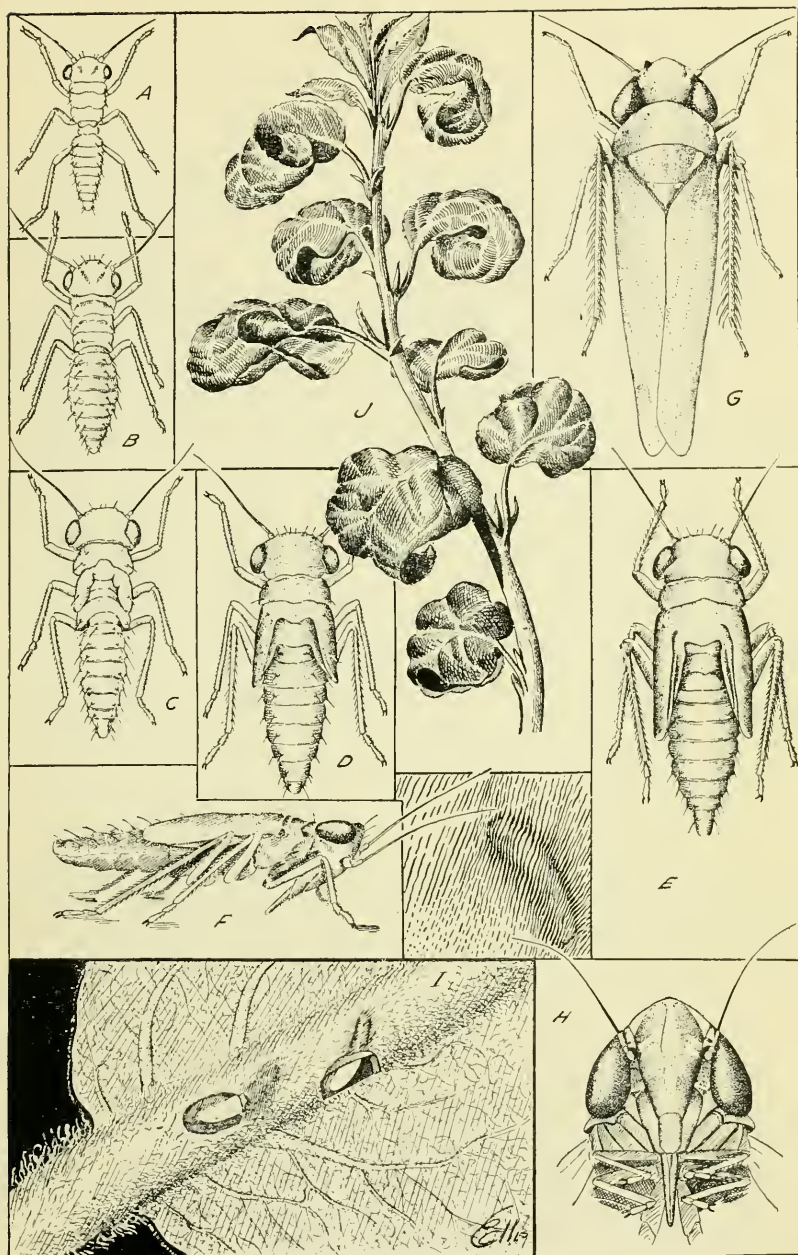


FIG. 2.—TERMINAL LEAVES OF NURSERY APPLE TREES CURLED BY THE
APPLE LEAFHOPPER.

THE APPLE LEAFHOPPER.



THE APPLE LEAFHOPPER.

A, First nymphal stage; *B*, second stage; *C*, third stage; *D*, fourth stage; *E*, fifth stage; *F*, side view of fifth stage; *G*, adult; *H*, front view of head of adult; *I*, eggs in tissue on underside of apple leaf; *J*, curled condition of terminal leaves due to attack by the apple leafhopper on apple.

As a result of the continued checking of the growth, due to the infestation of the apple leafhopper, nursery apple trees often require an additional year's growth before they become of marketable size.

EXTENT OF INJURY AND INFLUENCING FACTORS.

The extent of injury varies according to the age of the nursery stock and according to the differences in the character of growth of apple varieties.

Seedlings and the initial growth of buds and grafts are very seriously injured. Nursery stock at this stage is in its most critical period of growth and is injured very easily. Furthermore, any injury at this stage is not readily outgrown.

After the first year's growth the more vigorous varieties become partially immune to serious injury and succeed in maintaining a satisfactory growth, while slow-growing and tender-leaved varieties are at all times badly injured by the attack of this insect. This is easily understood since, even under normal conditions, the latter make but a very ordinary growth and are entirely unable to withstand a serious check. Among the varieties most severely injured in Pennsylvania nurseries Red Astrachan, a particularly slow grower during the first two seasons, ranks first, followed by Smith's Cider, Starr, Early Harvest, Summer Rambo, Delaware Winter, Wagoner, Golden Russet, Early Ripe, Wealthy, and Alexander.

DESCRIPTION OF STAGES.

Egg.

PL. III, I.

The egg is elongate, subcylindrical in form, very delicate, slightly curved from end to end, somewhat rounded at both ends but more so at the anterior one. When first deposited it is rather transparent but in a few days it changes to a pale yellow color, while a small white cap forms at the anterior end through which the red eyes of the immature nymph are perceptible.

Average length of 15 eggs 0.82 mm., width 0.25 mm.

NYMPH.

PL. III, A-F.

First instar.—Color pale white, changing to a light yellowish green after feeding. Eyes dull red. Small pale spines on the dorsal side of the head, thorax, and abdomen; the latter with four spines to each segment arranged in two longitudinal rows along each side, one spine situated dorso, laterally, the other ventro-laterally. Posterior margin of metathorax blunt. First two segments of antennæ pale, the remainder dusky. Average length of 16 specimens 1 mm.

Second instar.—General color light yellowish green. Eyes lose some of their red color. Posterior border of metathorax sharp in outline. First two segments of antennæ light yellow, remainder dusky. Average length of 16 specimens 1.30 mm.

Third instar.—General color pale yellowish green. Eyes almost pearl white. Body more robust than in first two stages. Wing pads appear as lateral buds extending

to the hind margin of the first abdominal segment. Spines darker and more prominent. Average length of 16 specimens 1.85 mm.

Fourth instar.—Head and thorax yellowish green; abdomen yellow in color. Eyes pearl white. Wing pads extend to hind margin of second abdominal segment. Spines prominent. Average length of 16 specimens 2.1 mm.

Fifth instar.—Head and thorax pale green; abdomen yellow. Eyes dull white. Wing pads extend to or nearly to the hind margin of the fourth abdominal segment. First two antennal segments green, remainder dusky. Body broader than in previous stage. Average length of 16 specimens 2.6 mm.

ADULT.

Pl. III, G, H.

General color of adult pale green; face with a white median longitudinal line in older specimens but composed of a series of white spots in newly hatched individuals; median line extending from a point midway between the ocelli to a point half the distance to lower margin of clypeus; two short white diagonal bands on each side of median line, the lower one the smaller; a short white line, often merely two spots, beyond the diagonal and just above the antenna; a faint white line midway between the ocellus and eye; antennæ 1 mm. in length, arising near the lower frontal border of the eyes; clypeus one-third longer than broad; loræ narrow, not reaching the tips of clypeus, concave below eyes; genæ almost as long and half as broad as clypeus, with one or two faint white spots. Vertex dark green with a median white line, narrowest in middle, its length equal to distance between the ocelli; a white band on each side, dorso-lateral and diagonal to median line. Two ocelli present, marked by two white spots and situated on frontal margin of vertex, their distance apart equal to twice that from the eye to the ocellus; eyes dull white, reddish brown after death. Pronotum pale green, hind margin very pale, with eight white spots along the frontal margin, the last spot at each end small and often fused with the one next to it so as to form only six spots; mesonotum with two parallel white longitudinal lines centrally located and connected by a traverse one in the form of a letter H, a faint white diagonal line present on each lateral margin; scutellum small with a large white triangular area in the center and a small spot on each side along the frontal margin. Abdominal segments yellowish green with transverse yellow stripes on their hind margins, anal segment dark green. Wings semitransparent, pale yellowish green. Legs green, tarsi dusky at the tips. Sexual appendages ciliated in both sexes. Average length of 16 specimens 3.12 mm.

ALLIED SPECIES.

Three other species of *Empoasca* were found associated with *E. mali* on the foliage of nursery apple trees at West Chester, Pa. These species were determined by the late Otto Heidemann, of the Bureau of Entomology, as follows: *E. birdii* Goding, *E. flavescens* (Fabricius), and *E. unicolor* Gillette. *Birdii* and *flavescens* are very closely allied species, the former being considered by Gillette to be merely a color variety of the latter; these two species resemble *mali* quite closely and they may be easily mistaken for it. *Unicolor*, on the other hand, differs markedly from any of the above three and is readily distinguished from them.

Birdii differs from *mali* by its smaller size and paler color, by the presence of smoky markings on the elytra, and by the three white spots on the pronotum.

No attempt was made to study the life history and habits of *birdii* but they are probably much the same as those of *mali*. From

field observations it was found that this species hibernates in the adult stage in woodlands near the nursery at West Chester. The adults become active in the spring about a week earlier than *mali*, confining their feeding at first to the foliage of skunk cabbage. From this plant they scatter to grasses and weeds beneath the apple trees in the nursery a few days prior to the first appearance of *mali*. During the early spring they prefer to feed on any low green vegetation in the nursery row, and never become abundant on the foliage of apple until about mid-season. At this time they appear in numbers associated with *mali* on the terminal leaves. The extent of damage caused by *birdii* is small compared with that caused by the common apple leafhopper, and for this reason little attention has been paid to it heretofore.

Flavescens differs from *birdii* by the absence of the characteristic white markings of the pronotum and the smoky bands crossing the elytra.

This species is allied very closely to *birdii* in appearance, and probably in habits and life history, but it is less abundant on the apple.

Unicolor is readily separated from *mali* by the absence of the conspicuous white markings of the face and the notum, by its greater length and robustness, and by the presence of a pale white spot on the middle of the anterior margin of the pronotum and a blue blotch on the scutellum.

Few field observations were obtained in regard to the habits of *unicolor*. The nymphs of the first brood were found on apple at approximately the same date and about as abundantly as those of *mali* at Hagerstown, Md. The adults of this species do not confine their attack to the terminal leaves, being found more frequently on the lower part of the trees. This species was taken in scant numbers on apple in the vicinity of West Chester and the injury caused by it was negligible.

LIFE HISTORY AND HABITS.

METHODS OF STUDY.

In studying the life history of the two species of apple leafhoppers concerned in this bulletin all data were obtained under outdoor conditions by rearing the insects on young apple stock in the nursery row. Seedlings were planted out early in the spring of 1915 and again in 1916 on a plot of ground at one end of a few nursery rows.

Riley cages and arc-light globe cages (Pl. II, A) were used for obtaining records of the length of the egg stage, the extent of reproduction per female, and the longevity of adults of the different broods. The globe cages were well shaded from the sun by means of large muslin covers over their tops, while ventilation was obtained both from above and below. With the use of such cages practically normal conditions were secured for the rearing of the leafhopper

material. The plants were encaged before the hibernating adults made their appearance in the nursery, thereby preventing outside infestation.

Special cages were constructed for experiments in determining the length of the nymphal stages. Various types of cages were tried in an effort to secure one in which the nymph could be reared under as nearly normal conditions as possible.

The type of cage finally decided upon was made as follows: A piece of thin sheet-cork was cut about 2 inches square, in the center of which a 1-inch square hole was made. White muslin cloth was stretched tightly over one side of the cork and glued fast so as to cover the center hole. Heavy wadding cut to the shape of the cork, but leaving the center open, was glued to the other side. With the muslin side out, the cage was then placed over a newly hatched nymph on the lower surface of a leaf. A square of stiff cardboard of the same size as the cork was placed on the upper side of the leaf, and the cardboard, leaf, and cage were fastened together by paper clips. The young nymph within the cage received ventilation from both sides, through the porous wadding and through the muslin top. The leaf tissue was protected against injury by the cardboard on its upper surface and by the wadding on its lower surface. The nymph was examined daily by removing the paper clips and lifting the cage slightly; in this manner a record of the molts was obtained.

Although this cage was a little heavy when used on the small leaves of seedlings, it proved satisfactory when fastened to the larger leaves of two-year trees. For this reason the nymphal stages were obtained by transferring newly hatched nymphs from globe cages to the cork cages on uninfested leaves of older trees in the nursery row.

NUMBER OF GENERATIONS.

There are three generations of the apple leafhopper at West Chester, Pa. These generations overlap slightly but they are easily distinguished by the resultant injury caused by each. The first generation, covering the period from the time of egg deposition by the overwintered females to the death of the first-brood adults, extends from the last week in May to the first week in August. The second generation covers the period from the first week in July until the latter part of September. The third generation, including the hibernating adults, lasts from the first week in September until the early part of July of the following season. Adults of this generation hatch during the first week in September and remain on the trees until late in November when they seek shelter for the winter. In the spring of the following year overwintered adults are found on the trees from the last week in May until death, which occurs during June and early July.

Forbes and Hart (10) in 1900 mentioned the occurrence of four or more generations in Illinois. In 1908 Washburn (15) suggested that there were two and possibly three generations in Minnesota. R. L. Webster (18) in 1910 recorded four generations at Ames, Iowa. E. H. Gibson, of the Bureau of Entomology, has noted as many as five generations in southern Missouri, and six in southern Mississippi.

THE EGG.

The eggs are laid singly in the sides of the mid-vein and occasionally in the smaller veins of the terminal leaves. They are deposited in pockets just under the epidermis, usually lying in a longitudinal position. It is very difficult to locate the eggs as they are the same color as the tissue in which they are embedded, while the epidermis under which they are hidden is covered by the pubescence of the leaf. When the pubescence is removed, the tissue covering the egg appears slightly distorted and eventually becomes discolored. In making dissections of the leaf tissue the delicate egg is often crushed, whereupon the egg contents may be mistaken for the plant juice in the vein. When ready to hatch, the immature nymph pushes its head through the anterior end of the eggshell and forces a tiny hole in the thin epidermal leaf-covering, slowly drawing its body free from the enveloping tissue.

Eggs of *Empoasca mali* have been found in the leaves of the following host plants: Apple, pear, peach, plum, cherry, quince, alfalfa, beet, and potato.

Adults of all three generations deposit summer eggs in leaves in the manner mentioned above. Washburn (15) stated in 1908 that the last-brood adults of this species deposit winter eggs under the bark of nursery apple trees in Minnesota, and that the nymphs hatching therefrom the following spring attack the lower leaves of the trees. Webster (18) in 1910 made similar observations in Iowa. At West Chester, Pa., the apple leafhopper certainly does not pass the winter in the egg stage. Several experiments were made in the attempt to obtain winter eggs by confining numerous pairs of third-brood adults in cages, but all proved unsuccessful. Field observations for two seasons on several thousand trees also substantiate the above view. However, winter eggs of the rose leafhopper (which will be treated later) were found in abundance in this locality, the nymphs of which confine their feeding to the lower leaves of the trees.

THE NYMPH.

The newly-hatched nymphs are very small, wingless, white in color, and of the same form as the adults. Immediately after hatching they settle down to feed, inserting their minute beaks in the leaf tissue and sucking the plant juices. A day or two after taking food into

their bodies the young nymphs change to a pale green color, which is the characteristic color during the remainder of their nymphal life. The nymphs pass through five stages of development before they reach maturity, molting and increasing in size at the completion of each stage. The nymphs are very agile in their movements and run in a zig-zag or sidling manner; only fourth and fifth stage nymphs are able to hop.

The first nymphs of the season appear on the trees about June 1, and the nymphal infestation is at its height about three weeks later.

THE ADULT.

The adults are very active, especially on warm, sunny days, when they rise from the trees in swarms at the least disturbance. During flight the hoppers seldom rise over the tops of the trees but fly sidewise to the next nursery row.

Records have appeared stating that this insect is strongly attracted to artificial light, but this view is contrary to observations made by the writer. Among the leafhoppers found swarming around electric lights the two allied species *E. flavescens* and *E. birdii* were far more abundant than this species.

The overwintered adult leafhoppers become active during the warm days about the middle of May. Upon leaving their hibernating places they immediately disperse to apple blocks in the nursery. The first adults of the season appearing on apple stock in the nursery were found on May 18; by June 1 they become quite abundant on the foliage in this section. For several days they confine their activities to feeding on the underside of the terminal leaves. After feeding for about a week the adults mate and soon begin depositing the first-brood eggs.

Adults of all three generations have the same habits on apple. Third-brood adults feed on apple foliage in the fall until cold weather sets in. Prior to going into hibernation they collect on the lower leaves of the trees and on several varieties of low-growing weeds in the nursery row, being especially abundant on sorrel (*Rumex* sp.).

LONGEVITY OF OVERWINTERED ADULTS.

Data on the length of life of the adult apple leafhoppers were obtained with great difficulty, due to their activity. A Riley cage was used in this experiment in which 50 adults were confined on a young apple tree. The newly transforming nymphs were removed from the foliage from time to time to prevent confusing them with the adults. During the progress of the examinations a few adults made their escape. A record of the date on which the adults died is given in Table I. It will be noted that death occurred in most cases by July 1. From observations in the field it was found that practically

all overwintered adults had disappeared from the trees by the first week in July.

TABLE I.—*Longevity of overwintered adult apple leafhoppers; 50 adults placed in cage June 8, 1915.*

Date of examination.	Number dead.	Date of examination.	Number dead.
June 20.....	4	June 30.....	1
June 21.....	1	Do.....	14
June 22.....	6	July 1.....	1
Do.....	11	July 3.....	1
June 23.....	2	July 12.....	1
June 24.....	4	July 13.....	2
June 25.....	5	July 14.....	1
June 26.....	1	July 15.....	2
June 27.....	3	July 16.....	1
Do.....	11	July 17.....	1
June 28.....	2	July 18.....	1
June 29.....	2	July 19.....	2

¹ Escaped.

EXTENT OF REPRODUCTION BY OVERWINTERED FEMALES.

Pairs of overwintered adults were placed on young trees in globe cages to determine the number of eggs deposited by a female in confinement. The adult leafhoppers were allowed to remain on the foliage until they died. Examinations were made from time to time and a record was kept of the number of nymphs removed at each examination. This method of obtaining the extent of reproduction does not take into consideration the number of eggs that failed to hatch; however, it shows approximately the number of eggs deposited by a single female.

Two experiments were carried out and averages of 27 and 28 eggs per female hatched in the respective cages. In Table II the number of nymphs removed is given.

TABLE II.—*Number of first-brood nymphs produced by overwintered adult apple leafhoppers in confinement, West Chester, Pa., 1915.*

CAGE No. 1.—TWO PAIRS OF OVERWINTERED ADULTS PLACED IN CAGE ON YOUNG APPLE TREE JUNE 9, 1915.

Date of examination.	Number of first-brood nymphs removed.	Date of examination.	Number of first-brood nymphs removed.
June 24.....	43	July 7.....	2
June 26.....	2	July 30.....	0
June 29.....	6		
July 1.....	1	Average.....	27

CAGE No. 2.—THREE PAIRS OF OVERWINTERED ADULTS PLACED IN CAGE ON YOUNG APPLE TREE JUNE 7, 1915.

Date of examination.	Number of first-brood nymphs removed.	Date of examination.	Number of first-brood nymphs removed.
June 24.....	31	July 7.....	10
June 26.....	14	July 10.....	1
June 29.....	15	July 20.....	3
June 30.....	4	July 30.....	0
July 1.....	1		
July 3.....	5	Average.....	28

FIRST GENERATION.

FIRST BROOD OF EGGS.

Length of incubation period.—The adult females are very rarely seen depositing eggs since they are very agile in their movements and take flight at the slightest disturbance. Moreover, even though a female is observed in the act of oviposition, the egg is seldom detected, as it is inserted under the epidermis and is further hidden by the downy pubescence of the leaf. For these reasons only approximate records of the length of the egg stage could be secured.

Data on the incubation period were obtained by confining copulating pairs of overwintered adults on a seedling tree in a globe cage. The adults were removed after 24 hours and a daily record was kept of the nymphs as they hatched. The length of the egg stage, together with the average mean temperature for the entire period, is given in Table III. The average incubation period was 7.5 to 9.5 days; the maximum, 10 to 12 days; the minimum, 5 to 7 days.

TABLE III.—*Length of incubation period of first-brood eggs deposited by overwintered females of the apple leafhopper in confinement, West Chester, Pa., 1915.*

TWENTY PAIRS OF OVERWINTERED ADULTS PLACED ON APPLE TREE JUNE 13, 1915, 12 M.; ADULTS REMOVED JUNE 14, 12 M.

Date of removal of newly hatched nymphs.	Number of nymphs removed.	Length of incubation period.	Average temperature for entire period.
1915.			
June 20, 12 m.	2	Days. 5 - 7	°F. 79.56
June 21, 12 m.	47	6 - 8	78.61
June 22, 12 m.	30	7 - 9	77.00
June 23, 12 m.	10	8 - 10	75.90
June 24, 12 m.	4	9 - 11	75.20
June 25, 12 m.	1	10 - 12	75.07
Average		7.5- 9.5	76.89

FIRST BROOD OF NYMPHS.

Length of stages.—The length of the nymphal stages and of the entire nymphal period was obtained by confining newly hatched nymphs in the cork cages described on page 8. Each cage was examined daily and a record made of the length of each stage, the cast skins being removed from the cages after each molt. The length of each stage and of the entire nymphal period is shown in Table IV; the average mean temperature for each nymphal period is also included. The average length of the nymphal period for 22 nymphs was 18.7 days; the maximum, 22 days; the minimum, 15 days.

TABLE IV.—*Length of nymphal stages of the first brood of the apple leafhopper at West Chester, Pa., 1915.*

First brood, June and July.

Date of hatching.	First molt.	First stage.	Second molt.	Second stage.	Third molt.	Third stage.	Fourth molt.	Fourth stage.	Fifth molt.	Fifth stage.	Total nymphal period.	Average mean temperature for nymphal period.
1915.	1915.	Days.	1915.	Days.	1915.	Days.	1915.	Days.	1915.	Days.	Days.	°F.
June 12	June 15	3	June 17	2	June 21	4	June 25	4	June 30	5	18	75.18
Do...	June 16	4	June 18	2	Do...	3	June 26	5	July 1	5	19	75.47
Do...	June 18	6	June 21	3	June 25	4	June 29	4	July 3	4	21	75.79
Do...	June 16	4	June 19	3	June 22	3	June 27	5	July 1	4	19	75.47
June 13	Do...	3	June 20	4	June 24	4	Do...	3	July 2	5	19	75.20
Do...	June 17	4	Do...	3	June 21	1	June 26	5	July 1	5	18	75.15
Do...	June 18	5	Do...	2	Do...	1	June 27	6	July 4	7	21	75.70
Do...	June 16	3	Do...	4	June 25	5	June 29	4	July 3	4	20	75.52
Do...	June 18	5	Do...	2	June 23	3	June 27	4	July 2	5	19	75.20
June 14	June 16	2	June 19	3	June 21	2	June 29	8	July 3	4	19	75.20
Do...	June 17	3	June 20	3	June 24	4	June 28	4	July 2	4	18	74.84
Do...	June 18	4	Do...	2	June 23	3	Do...	5	July 3	5	19	75.20
Do...	Do...	4	June 21	3	June 29	8	July 2	3	July 6	4	22	75.28
Do...	June 17	3	Do...	4	June 23	2	June 26	3	July 1	5	17	74.77
June 15	June 18	3	Do...	3	June 24	3	June 28	4	July 3	5	18	74.81
Do...	Do...	3	Do...	3	June 25	4	June 29	4	July 4	5	19	75.05
Do...	June 19	4	Do...	2	June 24	3	June 28	4	July 1	3	16	74.32
Do...	Do...	4	June 22	3	June 27	5	July 1	4	July 6	5	21	74.95
June 18	June 21	3	June 26	5	June 29	3	July 3	4	Do...	3	18	74.36
Do...	June 20	2	June 24	4	Do...	5	July 2	3	Do...	4	18	74.36
June 19	June 21	2	Do...	3	June 26	2	June 29	3	July 4	5	15	74.06
June 23	June 26	3	June 30	4	July 4	4	July 8	4	July 11	3	18	75.07
Average	.....	3.5	.....	3	.....	3.4	.....	4.2	.....	4.5	18.7	75.04

FIRST BROOD OF ADULTS.

Longevity.—First-brood adults were confined in a Riley cage to determine the length of life. Most of the hoppers died by August 1, as shown in Table V.

TABLE V.—*Longevity of first-brood adult apple leafhoppers; 50 adults placed in cage July 2, 1915.*

Date of examination.	Number dead.	Date of examination.	Number dead.
July 7.....	6	July 24.....	1
July 8.....	3	July 26.....	2
July 9.....	6	July 27.....	3
July 10.....	1	July 30.....	4
Do.....	1 ²	July 31.....	1
July 11.....	2	Aug. 2.....	3
July 12.....	1	Aug. 4.....	2
July 13.....	3	Aug. 5.....	1
July 17.....	5	Do.....	1
July 24.....	1	Aug. 6.....	1

¹ Escaped.

Extent of reproduction.—Two globe cage experiments were made to determine the extent of reproduction by a first-brood female in confinement. In one cage two pairs of adults, in the other three pairs were confined until death occurred. The average number of eggs

deposited per female in cage 1 was approximately 24; in cage 2, approximately 22. (See Table VI.)

TABLE VI.—*Number of second-brood nymphs produced by first-brood adult apple leafhoppers in confinement, West Chester, Pa., 1915.*

CAGE No. 1.—TWO PAIRS OF FIRST-BROOD ADULTS PLACED IN CAGE ON YOUNG APPLE TREE JUNE 30, 1915.

Date of examination.	Number of second-brood nymphs removed.	Date of examination.	Number of second-brood nymphs removed.
July 13.....	14	July 27.....	1
July 17.....	1	July 30.....	1
July 20.....	22	Aug. 10.....	0
July 22.....	8		
July 24.....	1	Average.....	24

CAGE No. 2.—THREE PAIRS OF FIRST-BROOD ADULTS PLACED IN CAGE ON YOUNG APPLE TREE JUNE 30, 1915.

July 14.....	6	July 29.....	11
July 17.....	3	July 30.....	3
July 20.....	17	Aug. 10.....	0
July 22.....	6		
July 24.....	5	Average.....	22
July 27.....	15		

SECOND GENERATION.

SECOND BROOD OF EGGS.

Length of incubation period.—As will be noted in Table VII, the length of the egg stage of this brood is somewhat shorter than that of the first brood. This fact undoubtedly is due to the higher temperatures occurring throughout the incubation period of the second-brood eggs. As in Table III only an approximation of the length of the incubation period was obtained. The average incubation period of second-brood eggs was 6 to 8 days; the maximum, 9 to 11 days; the minimum, 3 to 5 days.

TABLE VII.—*Length of incubation period of second-brood eggs of the apple leafhopper, West Chester, Pa., 1915.*

TWENTY-FIVE PAIRS OF FIRST-BROOD ADULTS PLACED ON APPLE TREE JULY 7, 1915, 3 P. M.; ADULTS REMOVED JULY 8, 3 P. M.

Date of removal of newly hatched nymphs.	Number of nymphs removed.	Length of incubation period.	Average temperature for entire period.
1915.		<i>Days.</i>	<i>° F.</i>
July 12, 3 p. m.....	9	3-5	77.08
July 13, 3 p. m.....	8	4-6	77.42
July 14, 3 p. m.....	6	5-7	77.50
July 15, 3 p. m.....	15	6-8	77.66
July 16, 3 p. m.....	13	7-9	78.05
July 17, 3 p. m.....	12	8-10	78.86
July 18, 3 p. m.....	1	9-11	79.54
Average.....		6-8	78.01

SECOND BROOD OF NYMPHS.

Length of stages.—The length of the stages and of the entire nymphal period of this brood was slightly shorter than in the case of first-brood nymphs. Table VIII shows that the average nymphal period of second-brood nymphs was 15.8 days; the maximum, 17 days; the minimum, 15 days.

TABLE VIII.—*Length of nymphal stages of the second brood of the apple leafhopper at West Chester, Pa., 1915.*

SECOND BROOD, JULY AND AUGUST.

Date of hatching.	First molt.	First stage.	Second molt.	Second stage.	Third molt.	Third stage.	Fourth molt.	Fourth stage.	Fifth molt.	Fifth stage.	Total nymphal period.	Average mean temperature for nymphal period.
1915.	1915.	Days.	1915.	Days.	1915.	Days.	1915.	Days.	1915.	Days.	Days.	°F.
July 14	July 17	3	July 19	2	July 22	3	July 25	3	July 30	5	16	79.70
July 17	July 20	2	July 23	4	July 26	3	July 30	4	Aug. 3	4	17	80.22
Do...	July 20	3	July 22	2	July 24	2	July 28	4	Aug. 1	4	15	80.50
July 20	July 22	2	July 23	1	July 27	4	July 30	3	Aug. 5	6	16	79.05
Do...	do...	2	July 25	3	July 28	3	do...	2	Aug. 4	5	15	79.00
Do...	do...	2	do...	3	July 29	4	Aug. 1	3	Aug. 5	4	16	79.05
July 21	July 24	3	July 28	4	July 31	3	Aug. 3	3	Aug. 7	4	17	78.27
July 22	July 25	3	July 29	4	do...	2	Aug. 2	2	Aug. 6	4	15	79.40
July 23	do...	2	do...	4	July 30	1	do...	3	Aug. 7	5	15	78.56
Do...	July 26	3	do...	3	do...	1	Aug. 3	4	Aug. 8	5	16	78.52
Do...	July 25	2	July 28	3	do...	2	Aug. 2	3	Aug. 7	5	15	78.56
Do...	July 26	3	do...	2	do...	2	Aug. 3	4	Aug. 8	5	16	78.52
Do...	do...	3	July 27	1	do...	3	do...	4	do...	5	16	78.52
Do...	July 27	4	July 29	2	Aug. 1	3	Aug. 5	4	Aug. 9	4	17	78.38
Average		2.6		2.7		2.5		3.2		4.6	15.8	79.01

SECOND BROOD OF ADULTS.

Longevity.—In Table IX the date of death for 40 second-brood adults is recorded.

TABLE IX.—*Longevity of second-brood adults; 40 adults placed in cage Aug. 13, 1915.*

Date of examination.	Number dead.	Date of examination.	Number dead.
Aug. 17.....	4	Sept. 16.....	1
Aug. 23.....	2	Sept. 20.....	2
Aug. 26.....	10	Sept. 24.....	2
Sept. 1.....	4	Sept. 27.....	3
Do.....	13	Sept. 30.....	2
Sept. 13.....	5	Do.....	11
Do.....	11		

¹ Escaped.

Extent of reproduction.—Four separate experiments were made to determine the number of eggs deposited by a female of the second brood. Two, three, four, and five pairs of adults, respectively, were

placed in separate cages and a record of the number of eggs hatched was kept. The average number of eggs deposited per female was 19.5 in cage 1, 21 in cage 2, 20.2 in cage 3, and 18.4 in cage 4. The total average for the four cages was 19.8 eggs per female. (See Table X.)

TABLE X.—*Number of third-brood nymphs produced by second-brood adult apple leaf-hoppers in confinement.*

CAGE NO. 1.—TWO PAIRS SECOND-BROOD ADULTS PLACED IN CAGE ON YOUNG APPLE TREE AUG. 5, 1915.

Date of examination.	Number of third-brood nymphs removed.	Date of examination.	Number of third-brood nymphs removed.
Aug. 16.....	21	Sept. 7.....	0
Aug. 23.....	12	Average per female.....	19.5
Aug. 30.....	6		

CAGE NO. 2.—THREE PAIRS SECOND-BROOD ADULTS PLACED IN CAGE ON YOUNG APPLE TREE AUG. 5, 1915.

Aug. 16.....	12	Sept. 14.....	3
Aug. 23.....	29	Sept. 28.....	0
Aug. 31.....	14	Average per female.....	21
Sept. 4.....	5		

CAGE NO. 3.—FOUR PAIRS SECOND-BROOD ADULTS PLACED IN CAGE ON YOUNG APPLE TREE AUG. 5, 1915.

Aug. 16.....	37	Sept. 14.....	5
Aug. 23.....	24	Sept. 28.....	0
Aug. 31.....	8	Average per female.....	20.2
Sept. 4.....	7		

CAGE NO. 4.—FIVE PAIRS SECOND-BROOD ADULTS PLACED IN CAGE ON YOUNG APPLE TREE AUG. 9, 1915.

Aug. 23.....	34	Sept. 22.....	1
Aug. 31.....	18	Sept. 30.....	0
Sept. 4.....	25	Average per female.....	18.4
Sept. 14.....	14		

THIRD GENERATION.

THIRD BROOD OF EGGS.

Length of incubation period.—Three separate cages were used in the experiments on the length of the incubation period of third-brood eggs. The average incubation period was 9.6 to 10.3 days for cage 1; 9.5 to 11.5 days for cage 2; and 10 to 12 days for cage 3. (See Table XI.)

TABLE XI.—Length of incubation period of third-brood eggs of the apple leafhopper, West Chester, Pa., 1915.

CAGE NO. 1.—SIX PAIRS OF ADULTS PLACED ON APPLE TREE AUG. 6, 1915, 8 A. M.; ADULTS REMOVED AUG. 6, 4 P. M.

Date of removal of newly hatched nymphs.	Number of nymphs removed.	Incubation period.	Average temperature for entire period.
1915.		Days.	° F
Aug. 15, 4 p. m.....	12	8.6- 9.3	75.95
Aug. 16, 4 p. m.....	2	9.6-10.3	76.40
Aug. 17, 4 p. m.....	2	10.6-11.3	76.00
Average.....		9.6-10.3	76.11

CAGE NO. 2.—TEN PAIRS OF ADULTS PLACED ON APPLE TREE AUG. 9, 1915, 4 P. M.; ADULTS REMOVED AUG. 10, 4 P. M.

1915.		Days.	° F
Aug. 19, 4 p. m.....	11	8-10	75.15
Aug. 20, 4 p. m.....	16	9-11	75.00
Aug. 21, 4 p. m.....	5	10-12	74.87
Aug. 22, 4 p. m.....	3	11-13	75.07
Average.....		9.5-11.5	75.02

CAGE NO. 3.—TWENTY-FIVE PAIRS OF ADULTS PLACED ON APPLE TREE AUG. 13, 1915, 4 P. M.; ADULTS REMOVED AUG. 14, 3 P. M.

1915.		Days.	° F
Aug. 23, 4 p. m.....	6	8-10	74.65
Aug. 24, 4 p. m.....	43	9-11	74.95
Aug. 25, 4 p. m.....	38	10-12	74.70
Aug. 26, 4 p. m.....	9	11-13	74.57
Aug. 27, 4 p. m.....	3	12-14	73.89
Average.....		10-12	74.55

TABLE XII.—Length of nymphal stages of the third brood of the apple leafhopper at West Chester, Pa., 1915.

THIRD BROOD, AUGUST AND SEPTEMBER.

Date of hatching.	First molt.	First stage.	Second molt.	Second stage.	Third molt.	Third stage.	Fourth molt.	Fourth stage.	Fifth molt.	Fifth stage.	Total nymphal period.	Average mean temperature for nymphal period.
1915.	1915.	Days.	1915.	Days.	1915.	Days.	1915.	Days.	1915.	Days.	Days.	° F.
Aug. 12	Aug. 14	2	Aug. 17	3	Aug. 20	3	Aug. 22	2	Aug. 27	5	15	74.44
Do.	Aug. 16	4	Aug. 19	3	Aug. 21	2	Aug. 25	4	Aug. 30	5	18	73.10
Do.	Aug. 15	3	do.	4	Aug. 22	3	do.	3	Aug. 31	6	19	72.55
Do.	Aug. 16	4	do.	3	Aug. 23	4	Aug. 27	4	Sept. 3	7	22	72.32
Aug. 14	Aug. 15	1	Aug. 18	3	Aug. 21	3	Aug. 24	3	Aug. 30	6	16	72.50
Do.	Aug. 16	2	Aug. 19	3	Aug. 22	3	Aug. 25	3	Aug. 31	6	17	71.94
Do.	do.	2	do.	3	do.	3	do.	3	Sept. 1	7	18	71.78
Do.	do.	2	do.	3	Aug. 23	4	Aug. 27	4	Sept. 2	6	19	71.52
Do.	Aug. 17	3	do.	2	Aug. 24	5	Aug. 26	2	Sept. 1	6	18	71.78
Aug. 17	Aug. 20	3	Aug. 23	3	Aug. 26	3	Aug. 31	5	Sept. 6	6	20	71.76
Do.	do.	3	Aug. 22	2	Aug. 25	3	do.	6	do.	6	20	71.76
Do.	Aug. 21	4	Aug. 23	2	do.	2	Sept. 1	7	do.	5	20	71.76
Do.	do.	4	do.	2	Aug. 26	3	do.	6	Sept. 7	6	21	72.09
Do.	Aug. 20	3	Aug. 22	2	Aug. 25	3	do.	7	Sept. 6	5	20	71.76
Average.....		2.8		2.7		3.1		4.2		5.8	18.7	72.21

THIRD BROOD OF NYMPHS.

Length of stages.—The average nymphal period was 18.7 days; the maximum, 22 days; the minimum, 15 days. (See Table XII.)

THIRD BROOD OF ADULTS.

Attempt to rear a fourth brood of nymphs.—Third-brood adults which were reared in confinement were placed on young apple trees in globe cages in an attempt to rear a fourth brood of nymphs. Four experiments were carried out, pairs of adults being confined on August 24, September 14 and 30, and October 1. None of the adults was observed to mate and not a single fourth-brood nymph developed. The foliage was examined several times covering a period of six weeks or more after the adults were confined.

Number of winter eggs deposited.—Four globe cage experiments were conducted to determine whether the third and last brood adults of the apple leafhopper deposited winter eggs in the bark of apple trees. Pairs of adults were confined in four separate cages on August 24, September 14, September 30, and October 1. They were allowed to remain undisturbed on the trees until December 10, when the trees were brought into the laboratory and carefully examined for winter eggs under the bark. Not a single winter egg was found on any of the four trees.

TABLE XIII.—Daily maximum, minimum, and average temperatures taken at West Chester, Pa., from May 12 to Sept. 18, 1915.

Day of month.	May.			June.			July.			August.			September.		
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
1.....				80	64	72	86	76	81	96	82	89	72	66	69
2.....				60	54	57	84	68	76	91	79	85	73	66	69.5
3.....				59	48	53.5	88	76	82	75	67	71	81	66	73.5
4.....				80	59	69.5	84	75	79.5	84	76	80	83	72	77.5
5.....				84	70	77	80	72	76	83	77	80	84	74	79
6.....	74	67	70.5	75	70	72.5	76	68	72	80	70	75	86	76	81
7.....	77	65	71	84	71	77.5	82	72	77	68	63	65.5	86	74	80
8.....	70	60	65	80	70	75	80	68	74	84	72	78	86	71	78.5
9.....	63	54	58.5	76	66	71	83	66	74.5	82	70	76	86	78	82
10.....	66	55	60.5	76	61	68.5	86	76	81	80	70	75	90	76	83
11.....	68	58	63	84	74	79	80	73	76.5	80	72	76	86	78	82
12.....	72	60	66	88	75	81.5	87	72	79.5	79	71	75	84	74	79
13.....	80	59	69.5	86	78	82	84	75	79.5	85	78	81.5	88	82	85
14.....	81	60	70.5	89	76	82.5	85	71	78	84	73	78.5	88	80	84
15.....	79	54	66.5	84	72	78	84	74	79	84	74	79	86	80	83
16.....	62	50	56	83	75	79	89	74	81.5	85	77	81	88	76	82
17.....	71	62	66.5	84	74	79	91	83	87	75	68	71.5	88	74	81
18.....	61	50	55.5	83	77	80	92	82	87	70	58	64	81	70	75.5
19.....	74	52	63	83	76	79.5	90	82	86	76	64	70	.....	.....	.....
20.....	75	64	69.5	80	73	76.5	79	72	75.5	82	65	73.5	.....	.....	.....
21.....	66	59	62.5	77	65	71	78	68	73	76	71	73.5	.....	.....	.....
22.....	84	69	76.5	65	60	62.5	84	74	79	83	72	77.5	.....	.....	.....
23.....	72	66	69	69	61	65	81	68	74.5	83	73	78	.....	.....	.....
24.....	70	58	64	75	60	67.5	80	74	77	84	72	78	.....	.....	.....
25.....	76	68	72	81	66	73.5	84	74	79	76	68	72	.....	.....	.....
26.....	77	60	68.5	84	69	76.5	84	72	78	76	70	73	.....	.....	.....
27.....	79	64	71.5	78	68	73	82	69	75.5	70	60	65	.....	.....	.....
28.....	70	66	68	78	65	71.5	82	74	78	66	62	64	.....	.....	.....
29.....	69	63	66	78	67	72.5	86	78	82	66	60	63	.....	.....	.....
30.....	79	71	75	80	75	77.5	90	80	85	74	68	71	.....	.....	.....
31.....	80	70	75	.....	.....	.....	91	74	82.5	68	57	62.5	.....	.....	.....

The foregoing experiments indicate that third-brood adults of the apple leafhopper, under Pennsylvania conditions, do not deposit winter eggs, but merely feed on the foliage until the time arrives for them to seek shelter for the winter.

The daily temperature for the period of seasonal activity is given in Table XIII.

SUMMARY OF SEASONAL HISTORY.

The apple leafhopper passes the winter in the adult stage under rubbish in the nursery or more often under accumulations of leaves in adjoining woodlands. In the spring the overwintered adults make their appearance on the trees during the latter part of May and they feed on the underside of the terminal leaves for about 10 days before mating. The females deposit their eggs in the veins of the terminal leaves, the average length of the incubation period of the first-brood eggs being approximately one week. The feeding period of this brood of nymphs extends from May 30 until about the middle of July, the nymphs being most abundant during the third week in June. The length of the first-brood nymphal period varies from 15 to 22 days, the average being 18.7 days. First-brood adults continue to emerge from June 20 to July 20. (See fig. 2.)

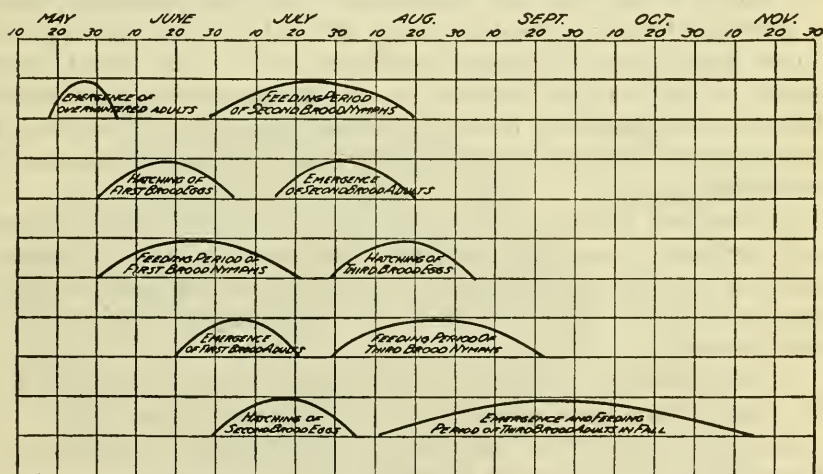


FIG. 2.—Seasonal history of the apple leafhopper at West Chester, Pa., 1915.

Second-brood eggs hatch from the latter part of June until about August 1, the length of the incubation period being about one week. The second-brood nymphs commence to appear about the last part of June, the larger percentage having developed into adults by the middle of August. The average length of the second nymphal period is 15.8 days; the maximum and minimum, 17 and 15 days, respectively. Second-brood adults appear on the trees from the middle of July until about a month later.

The third-brood eggs hatch from July 30 until about September 1, the length of the egg stage of this brood being about 9 to 10 days. Third-brood nymphs are found on the foliage from August 1 until about the third week in September, the average length of the entire nymphal period being 18.7 days or approximately the same as that of the first brood. By the middle of August the nymphs begin to transform to adults and by the end of September all the nymphs have disappeared. The third-brood adults remain on the trees until cold weather sets in when they gradually disperse to the hibernating places.

NATURAL ENEMIES.

The apple leafhopper is evidently quite free from the attack of parasites. Only one record of parasitism has appeared in the literature, R. L. Webster in 1913 having noted the pupa of an egg parasite which, however, died before reaching maturity.

A few cases of parasitism of adults by a dryinid have been seen at West Chester, Pa., but no adults of this parasite were reared successfully. However, two dryinid females were captured in the field while in the act of ovipositing in the abdomen of nymphs of *Empoasca mali*. These specimens were determined by Mr. J. C. Crawford, of the United States National Museum, as *Aphelopus albopictus* Ashm.

Probably the most effective enemy of this leafhopper is the predacious heteropteron *Triphleps insidiosus* Say. This small black insect, which is rather common on the foliage during midsummer, feeds on the nymphs by thrusting its beak into their soft bodies. It is actually of little importance, however, in reducing the numbers of leafhopper nymphs.

Spiders and various species of mites have been noted attacking and devouring nymphs on several occasions. In one instance an adult of the pear-leaf blister-mite was found preying on a first-stage nymph. Ladybeetle larvæ also are predacious on nymphs to a small extent.

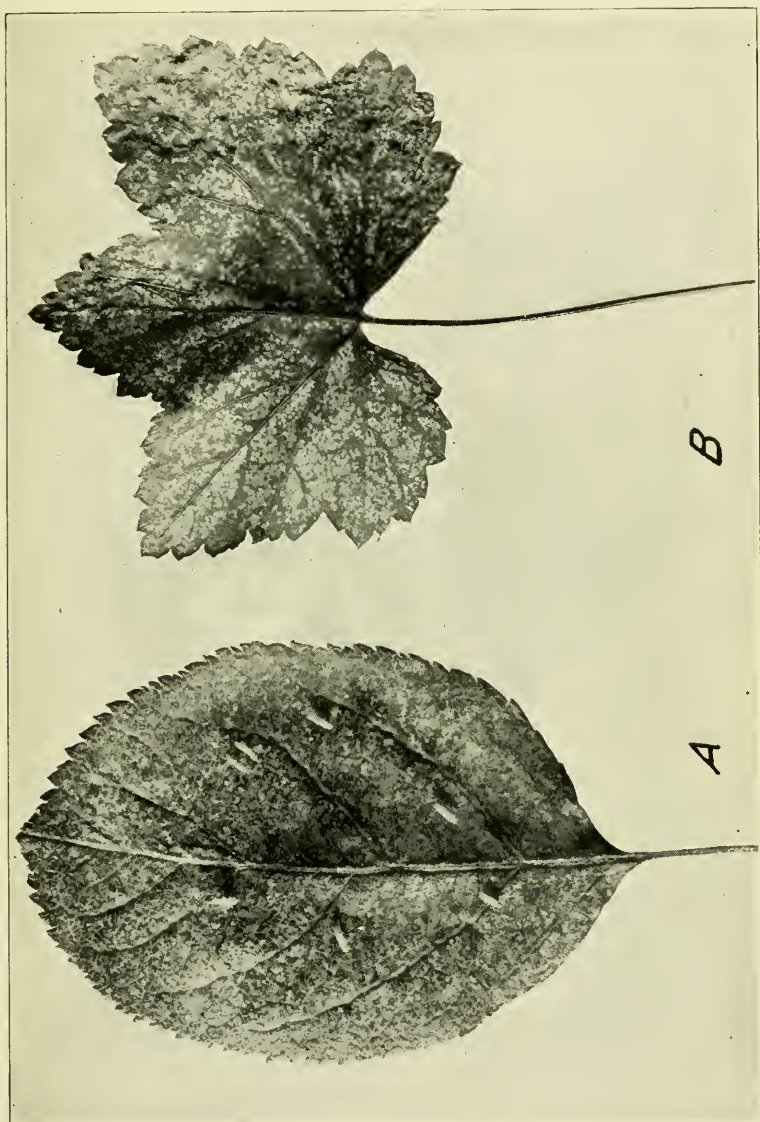
R. L. Webster (18) records larvæ of aphid lions and a dipteran of the family Empididae as feeding on the nymphs in Iowa.

As in the case of other species of leafhoppers, both the nymphs and the adults are often caught in spider webs.

THE ROSE LEAFHOPPER, *Empoa rosae* (Linn.).

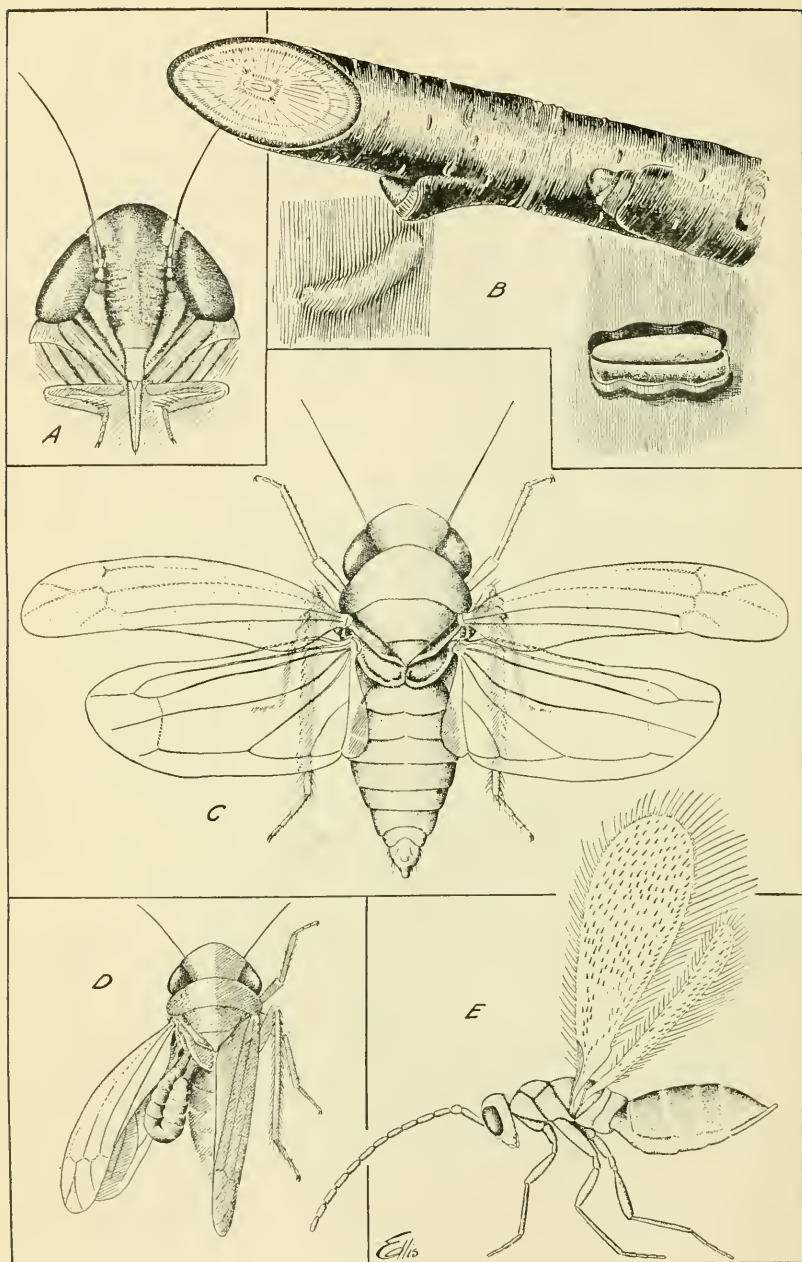
HISTORY.

The rose leafhopper was originally described by Linnaeus (21, p. 439) in Europe in 1758 as *Cicada rosae*. Since that time this insect has been placed in several genera by various writers in Europe and North America. It was first listed by Burmeister in 1835 as *Typhlocyba rosae* Linn., and under this name it has been commonly known in



THE ROSE LEAFHOPPER (*EMPOA ROSAE*).

A, Typical injury to apple leaf caused by the rose leafhopper; *B*, injury to currant leaf.



THE ROSE LEAFHOPPER.

A, Front view of head of male; B, overwintering eggs under bark of apple twig; C, adult with wings spread; D, adult with larva of dryinid parasite protruding from the body; E, *Anagrus armatus nigricinctus*, parasite of winter egg.

entomological literature. The genus *Empoa* was erected by Fitch (22, p. 63) in 1851, and in 1889 Weed (25, p. 155) transferred *rosae* from *Typhlocyba* to *Empoa*. In recent years *rosae*, with a few exceptions, has been referred to under the genus *Typhlocyba*, owing to the persistent ignoring of *Empoa* Fitch.

This insect has been known as a pest of cultivated roses in several European countries for more than a hundred years. The first account of the rose leafhopper in this country was published by Harris (23, p. 199) in 1852, when he described it as *Tettigonia rosae*. Although brief mention has been frequently made of this hopper since Harris's time, the first record of it as an enemy of apple was made by Parrott (26) in 1909. Wilson and Childs (27) in 1915 were the first authors to treat of this insect at any length. They made a study of the rose leafhopper as a fruit pest in Oregon, giving the life history, habits, destructiveness, and remedial measures. Brittain (28), also in 1915, discussed this species as an enemy of apple in Nova Scotia.

SYNONYMY.

Empoa rosae (Linn.).

Cicada rosae Linn. Syst. Nat., ed. 10, v. 1, 1758, p. 439.

Typhlocyba rosae Burm. Handb. d. Ent., 2, 1835, p. 107.

Cicadula rosae Zett. Ins. Lap., 1840, p. 299.

Typhlocyba pteridis Dahlb. Kongl. Vet.-Akad. Handl., 1850, p. 179.

Tettigonia rosae Harr. Ins. Inj. to Veg., 2nd ed., 1852, p. 199.

Eupteryx rosae Marsh. Ent. Mo. Mag., v. 3, 1866-1867, p. 246.

Typhlocyba lactea Dougl. Ent. Mo. Mag., v. 12, 1875, p. 77.

Anomia rosae Fieber. Rev. d'Ent., v. 3, 1884, p. 124.

Empoa rosae Weed. Amer. Gard., July, 1889, p. 257.

ORIGIN AND DISTRIBUTION.

The rose leafhopper is undoubtedly of European origin, as it was known to Linnaeus more than a century before it was first recorded in this country. It probably was introduced from abroad in the egg stage on rose or apple stock.

It is distributed generally throughout the United States and has been taken from States forming the extreme northern, southern, eastern, and western limits of the country. It is apparently most abundant in the Northern States, particularly in the Pacific Northwest. In Canada, this insect has been reported from Nova Scotia, Ontario Province, and from British Columbia. In Europe it has been recorded from several localities in England, France, and Germany.

FOOD PLANTS.

This insect, although primarily a pest of rose and apple, is a rather general feeder. At West Chester, Pa., it has been taken feeding upon rose, apple, pear, peach, plum, cherry, quince, currant, gooseberry, raspberry, blackberry, grape, *Crataegus*, elm, oak, and cotton-

wood (*Platanus deltoides*). In addition, Wilson and Childs list strawberry, logan blackberry, and prune from Oregon. It is likely that this leafhopper will feed on the foliage of most plants belonging to the family Rosaceae.

CHARACTER OF INJURY.

The nymphs and adults of *Empoa rosae* confine their feeding entirely to the lower leaves of apple trees in the nursery. They congregate on the lower surfaces of the foliage and suck the plant juices by puncturing the leaf tissue with their tiny beaks. The first indication of the injury is the mottling of the leaves with yellowish or whitish spots at the points where the punctures were made. (See Pl. IV.) When the leaves become heavily infested they turn yellow, dry up, and drop to the ground prematurely. The foliage is never curled by this species, nor is the terminal growth checked, as in the case of injury by *Empoasca mali*.

A second type of injury is produced by the egg punctures made by the females in the fall during the oviposition period. The eggs are deposited under the bark of young apple trees, several hundred eggs often being placed in a single twig.

The injury produced by the rose leafhopper to apple nursery stock is of little importance, however, when compared with that caused by the more destructive apple leafhopper.

DESCRIPTION OF STAGES.

EGG.

Pl. V, B.

The winter egg is elongate oval, slightly crescentic in form, almost circular in cross section, and blunt at both ends. It is almost transparent at first, but when ready to hatch it changes to a milky white color, while the red eyes of the young nymph are visible through the smooth chorion.

Average length of 16 eggs 0.65 mm., width 0.19 mm.

NYMPH.

First instar.—Color of first-instar nymph pale white changing to light yellow after feeding. Eyes dull red. Small spines present on the dorsal side of the head, thorax, and abdomen; the latter with four spines to each segment arranged in two longitudinal rows on each side. Posterior margin of metathorax blunt. First two segments of antennæ pale, remainder dusky. Average length of 16 specimens 0.98 mm.

Second instar.—General color creamy white to light yellow. Eyes lose some of their red color, becoming lighter. Wing pads begin to appear as lateral buds. Posterior margin of metathorax sharp in outline. First two segments of antennæ yellow, remainder dusky. Average length of 16 specimens 1.27 mm.

Third instar.—General color light yellow. Eyes dull white. Body more robust than in first two stages. Wing pads extending to hind margin of the first abdominal segment. Spines darker and more prominent. Average length of 16 specimens 1.55 mm.

Fourth instar.—General color light yellow. Eyes almost pearl white with a brown central spot underneath. Wing pads extending to hind margin of the second abdominal segment. Spines very distinct. Average length of 16 specimens 2.03 mm.

Fifth instar.—General color as in previous stage. Eyes almost pearl white. Wing pads extending nearly to the hind margin of the fourth abdominal segment. Broader than in previous stage. Average length of 16 specimens 2.85 mm.

THE ADULT.

PL. V, A, C.

General color of adult creamy white to light yellow. Head rather pointed, pale yellow; face of male with a tint of orange color in the form of a central longitudinal stripe with several transverse radiating stripes; genæ pale, narrow, and almost as long as clypeus; loræ very narrow, sunken beneath the compound eyes. Vertex pale yellow with two semitransparent spots just above the ocelli, a faint median longitudinal semitransparent line extending from the hind margin half-way to the front margin, and a semitransparent line bordering each eye. Two ocelli present, situated on the frontal margin of the vertex, marked by two white spots with a dark center, distance apart twice that from the eye to the ocellus; eyes pearl white with a darkened center, ashen-gray after death. Pronotum light yellow with a semitransparent area in the center; mesonotum semitransparent with a large trapezoidal creamy area extending from the front to the hind margins, wider behind; a small cream colored area anteriorly on each side; scutellum cream-colored, sometimes with a semitransparent area caudad. Elytra transparent. First two segments of antennæ pale, flagellum dusky. Legs pale, tarsi dusky at tips. Sexual appendages slightly ciliated in female only. Average length of 12 specimens 3.00 mm.

LIFE HISTORY AND HABITS.

THE EGG.

Part of the rearing work in the life history of the rose leafhopper was conducted during the spring of 1915, the work being completed during the season of 1916. In obtaining data on the biology of this insect the same methods as devised for the study of the apple leafhopper were used.

Winter egg.—This leafhopper hibernates in the egg stage, winter eggs being deposited in the fall during the period extending from the last week in September to November 1. They are laid almost entirely under the bark of apple trees and rose bushes, though a few have been found in pear, quince, cherry, plum, currant, and *Crataegus*. The eggs are deposited singly, usually lying in a longitudinal position just under the epidermis, and they are placed in a distinct blister or pouch which measures 0.7 to 0.8 mm. in length. They are easily located by looking on the bark for the raised blister, which, as a rule, is slightly crescentic in outline. Winter eggs have been found in the bark of nursery apple trees from one to four years old; they are found in greatest numbers on the first year's growth of two-year trees. The favorite location for oviposition seems to be around the bases of the lowest limbs or on the trunk just below the first branches.

Summer eggs.—Summer eggs are laid by first-brood adults during July in the veins of the lower leaves.

THE NYMPH.

The nymphs of this species differ from those of *Empoasca mali* by their paler color, by their smaller size, and by the fact that they confine their activities entirely to the lower leaves of the trees. Though very active they are not quite as quick in their movements as the nymphs of the apple leafhopper.

As the young nymphs emerge from the eggs in the bark they make their way to the nearest leaves, where they immediately settle down to feed. In the vicinity of West Chester, Pa., the first nymphs of the season emerge about May 1, and by May 15 practically all the winter eggs have hatched. Generally speaking, the nymphs of this species are from three to four weeks old before the first nymphs of *Empoasca mali* appear on the terminal leaves.

THE ADULT.

Nymphs of the first brood transform to adults during the first two weeks in June and these adults feed on the foliage for several weeks before mating. Oviposition extends over a period of about two weeks during late June and early July, most of the first-brood adults dying by the end of July.

Second-brood adults begin to appear during the first week in August, and they remain on the trees until death, which occurs by November 1, after the winter eggs have been deposited. A few adults have been noticed on the trees as late as November 25. No rose leafhoppers, either in confinement or in the field, were observed to hibernate in the adult stage.

FIRST GENERATION.

FIRST BROOD OF EGGS.

The length of the incubation period of the first-brood eggs (i. e., the winter eggs) is 6 to 7 months. Eggs deposited during October hatch by the middle of May of the following year at the latest.

FIRST BROOD OF NYMPHS.

Nymphs newly hatched from winter eggs were confined in individual cork cages on uninfested leaves. The average length of the entire nymphal period, as indicated in Table XIV, was 33.4 days; the maximum, 36 days; the minimum, 30 days.

TABLE XIV.—*Length of nymphal stages of the first brood of the rose leafhopper on nursery apple trees at West Chester, Pa., 1915.*

First brood, May and June.

Date of hatching.	First molt.	First stage.	Second molt.	Second stage.	Third molt.	Third stage.	Fourth molt.	Fourth stage.	Fifth molt.	Fifth stage.	Total nymphal period.	Average mean temperature for nymphal period.
1915.	1915.	Days.	1915.	Days.	1915.	Days.	1915.	Days.	1915.	Days.	Days.	°F.
May 6	May 11	5	May 14	3	May 21	7	May 28	7	June 7	10	32	67.19
May 7	May 13	6	May 17	4	May 24	7	May 30	6	June 8	9	32	67.33
Do...	May 14	7	May 21	7	May 29	8	June 4	6	June 12	8	36	68.16
Do...	do...	7	May 22	8	May 28	6	June 2	5	June 10	8	34	67.47
Do...	May 15	8	do...	7	do...	6	June 3	6	June 11	8	35	67.79
Do...	May 12	5	May 20	8	May 26	6	do...	8	June 9	6	33	67.44
Do...	May 16	9	May 23	7	May 29	6	June 5	7	June 12	7	36	68.16
Do...	May 15	8	do...	8	May 30	7	June 4	5	June 11	7	35	67.79
May 8	May 13	5	May 21	8	May 27	6	June 3	7	do...	8	34	67.70
May 11	May 16	5	do...	5	do...	6	do...	7	June 10	7	30	67.85
Do...	May 17	6	May 22	5	May 28	6	do...	6	June 11	8	31	68.29
Average.....		6.4		6.3		6.4		6.3		7.8	33.4	67.74

FIRST BROOD OF ADULTS.

No attempt was made to obtain definite data on the longevity of first-brood adults. Ninety adults, however, were confined in a Riley cage on a young apple tree on May 31, 1916, and the last leafhoppers died on August 1; by this date many of the second-brood nymphs had appeared. Thus, the length of life of the adults of this brood is approximately two months.

SECOND GENERATION.

SECOND BROOD OF EGGS.

Length of incubation period.—An approximation of the length of the egg stage of second-brood eggs (i. e., the summer eggs) is shown in Table XV. The average length of the period was 25 days; the maximum, 27 days; the minimum, 23 days.

TABLE XV.—*Length of incubation period of summer eggs deposited by first-brood females of the rose leafhopper, West Chester, Pa., 1916.*

Four pairs of adults placed in confinement on apple tree July 28, 1916, 4 p. m.; adults removed July 29, 4 p. m.

Date of removal of newly hatched nymphs.	Number of nymphs removed.	Incubation period.	Date of removal of newly hatched nymphs.	Number of nymphs removed.	Incubation period.
1916.		Days.	1916.		Days.
Aug. 21.....	0	23-25	Aug. 25.....	0	23-25
Aug. 22.....	9	24-26	Aug. 26.....	0	24-26
Aug. 23.....	2	25-27	Aug. 27.....	0	25-27
Aug. 24.....	2		Aug. 28.....	0	

SECOND BROOD OF NYMPHS.

Length of stages.—In Table XVI the length of the stages and of the entire nymphal period is recorded. The average length of the nymphal period was 17.7 days; the maximum, 19 days; the minimum, 16 days. It will be noted that the length of the nymphal period of the second brood was much shorter and that the corresponding temperatures were much higher than in the case of the first-brood nymphs.

TABLE XVI.—*Length of nymphal stages of second brood of the rose leafhopper on nursery apple trees at West Chester, Pa., 1916.*

Second brood, July and August.

Date of hatching.	First molt.	First stage.	Second molt.	Second stage.	Third molt.	Third stage.	Fourth molt.	Fourth stage.	Fifth molt.	Fifth stage.	Total nymphal period.	Average mean temperature for nymphal period.
1916.	1916.	<i>Days.</i>	1916.	<i>Days.</i>	1916.	<i>Days.</i>	1916.	<i>Days.</i>	1916.	<i>Days.</i>	<i>Days.</i>	<i>°F.</i>
July 21	July 25	4	July 28	3	July 31	3	Aug. 3	3	Aug. 7	4	17	79.72
July 24	July 28	4	July 31	3	Aug. 4	4	Aug. 6	2	Aug. 10	4	17	80.13
July 25	July 27	2	do.	4	Aug. 3	3	do.	3	do.	4	16	80.38
Do.	July 28	3	Aug. 1	4	Aug. 5	4	Aug. 7	2	Aug. 12	5	18	80.55
Do.	July 31	6	Aug. 3	3	do.	2	Aug. 8	3	do.	4	18	80.55
July 28	do.	3	Aug. 4	4	Aug. 6	2	Aug. 9	3	Aug. 15	6	18	79.84
Do.	Aug. 1	4	do.	3	do.	2	do.	3	do.	6	18	79.84
Do.	do.	4	do.	3	do.	2	Aug. 10	4	Aug. 16	6	19	79.70
Do.	do.	4	Aug. 5	4	Aug. 8	3	Aug. 12	4	Aug. 15	3	18	79.84
July 30	Aug. 2	3	Aug. 6	4	do.	2	do.	4	Aug. 17	5	18	80.26
Do.	Aug. 4	5	do.	2	Aug. 10	4	Aug. 15	5	Aug. 18	3	19	80.40
Do.	Aug. 2	3	do.	4	Aug. 9	3	Aug. 13	4	do.	5	19	80.40
July 31	Aug. 5	5	Aug. 9	4	Aug. 12	3	Aug. 16	4	Aug. 19	3	19	80.75
Do.	do.	5	Aug. 8	3	do.	4	Aug. 15	3	do.	4	19	80.75
Aug. 3	Aug. 6	3	Aug. 10	4	Aug. 13	3	Aug. 16	3	Aug. 20	4	17	80.94
Aug. 4	Aug. 7	3	Aug. 9	2	do.	4	Aug. 17	4	Aug. 21	4	17	81.38
Do.	Aug. 6	2	Aug. 11	5	Aug. 15	4	Aug. 18	3	do.	3	17	81.38
Do.	Aug. 8	4	Aug. 12	4	do.	3	Aug. 17	2	Aug. 20	3	16	81.23
Do.	do.	4	Aug. 13	5	Aug. 16	3	Aug. 19	3	Aug. 22	3	18	81.68
Aug. 5	do.	3	Aug. 11	3	Aug. 15	4	Aug. 17	2	Aug. 21	4	16	81.29
Average		3.7		3.5		3.1		3.2		4.1	17.7	80.50

SECOND BROOD OF ADULTS.

Extent of reproduction.—Pairs of second-brood adults were confined in arc-light globe cages to determine the number of winter eggs deposited per female in the bark of apple. The data in Table XVII were obtained in the fall of 1915, and that in Table XVIII in 1916. The hoppers were allowed to remain on the trees until death. The average number of eggs deposited per female during the two experiments was 15.5 and 16, respectively.

Attempt to rear a third brood of nymphs.—A globe-cage experiment was conducted to determine whether second-brood adults would produce a third brood of nymphs. Ten pairs were confined on August 7 in two cages and examined at intervals until October 1. In no case

did any third-brood nymphs develop, only winter eggs being deposited by the females.

TABLE XVII.—*Number of winter eggs deposited in bark of apple trees by second-brood adults in confinement, West Chester, Pa., 1915.*

Cage.	Date of confinement.	Number of pairs confined.	Date of examination.	Number of eggs present.
	1915.		1915.	
1	Sept. 26	6	Nov. 25	98
2	Oct. 9	5	...do	78
	Total			176
	Average per female			16

TABLE XVIII.—*Number of winter eggs deposited in bark of apple trees by second-brood adults in confinement, West Chester, Pa., 1916.*

Cage.	Date of confinement.	Number of pairs confined.	Date of examination.	Number of eggs present.
	1916.		1916.	
1	Aug. 7	6	Nov. 7	104
2	Sept. 6	9	Nov. 8	120
	Total			233
	Average per female			15.5

In Table XIX the daily temperature is given for the period of seasonal activity, 1916.

TABLE XIX.—*Daily maximum, minimum, and average temperature taken at West Chester, Pa., from July 21 to Oct. 31, 1916.*

Day of month.	July.			August.			September.			October.		
	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.
1916.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
1.				85	74	79.5	84	78	81	53	45	49
2.				80	70	75	81	76	78.5	65	50	57.5
3.				78	74	76	72	66	69	70	53	61.5
4.				88	78	83	78	70	74	65	61	63
5.				88	77	82.5	83	72	77.5	75	59	67
6.				92	80	86	84	76	80	73	65	69
7.				91	82	86.5	86	78	82	70	62	66
8.				92	75	83.5	88	74	81	77	60	68.5
9.				85	76	80.5	76	68	72	82	70	76
10.				82	68	75	74	66	70	53	43	48
11.				86	78	82	72	60	66	62	50	56
12.				86	78	82	76	61	68.5	70	58	64
13.				74	70	72	81	65	73	56	54	55
14.				78	72	75	84	72	78	60	52	56
15.				80	74	77	72	64	68	60	45	52.5
16.				80	74	77	66	56	61	62	59	60.5
17.				90	80	85	70	62	66	68	60	64
18.				86	80	83	68	60	64	58	44	51
19.				90	82	86	62	51	56.5	67	56	61.5
20.				88	82	85	72	57	64.5	80	68	74
21.	80	72	76	93	75	84	72	56	64	57	49	53
22.	81	70	75.5	92	82	87	75	64	69.5	54	45	49.5
23.	84	76	80	92	82	87	76	68	72	56	44	50
24.	78	71	76	79	69	74	68	55	61.5	61	48	54.5
25.	76	74	75	84	66	75	66	57	61.5	64	46	55
26.	82	78	80	84	75	79.5	72	57	64.5	56	48	52
27.	90	75	82.5	86	74	80	79	66	72.5	58	49	53.5
28.	80	74	77	70	64	67	82	70	76	56	49	52.5
29.	80	74	77	74	64	69	72	56	64	61	46	53.5
30.	84	74	79	80	66	73	59	46	52.5	67	50	58.5
31.	92	85	88.5	82	65	73.5				62	50	56

SUMMARY OF SEASONAL HISTORY.

There are two generations of the rose leafhopper annually at West Chester, Pa. This insect hibernates in the egg stage, the eggs being deposited under the bark of the host plants. On apple stock in the nursery the winter eggs hatch from May 1 to May 15, and the newly hatched nymphs immediately attack the lower leaves of the trees. The feeding period of the first brood of nymphs covers approximately one month. The first adults of the season appear by the end of May. The latter feed for several weeks before mating and depositing the second brood of eggs in the foliage. The length of the life of the first-brood adults is about two months, most of them having disappeared by the first week in August.

The length of the incubation period of the second-brood eggs is about 25 days, the first eggs hatching about July 20. Due to the higher temperatures, the length of the nymphal period of this brood is comparatively shorter than that of the spring brood of nymphs. Second-brood nymphs, on an average, attain the adult stage in 17 days. By the latter part of August, practically all the nymphs have transformed to adults. The adults feed for about a month before mating, which takes place during the latter part of September. Females deposit the winter eggs throughout the month of October, soon after which they die. The last adults of the season were found on the trees on November 25.

NATURAL ENEMIES.

The most efficient enemies of the rose leafhopper are two species of hymenopterous egg parasites belonging to the superfamily Proctotrypoidea. These parasites were determined by Mr. A. A. Girault, of the Bureau of Entomology, as *Anagrus epos* Girault and *Anagrus armatus* Ashm. var. *nigriventris* Girault. (See Pl. V, E.) These two parasites were reared from the winter eggs only, and they emerged both in the fall and in the spring. In the fall they emerged from October 15 to November 1, while in the spring they were reared in abundance about one or two weeks after the hatching of the winter eggs.

These egg parasites are a valuable factor in reducing the destructive numbers of the leafhopper. At West Chester, Pa., from 65 to 70 per cent of the winter eggs were parasitized during 1916. Both of these species evidently are widely distributed, as they have been reared from the eggs in apple twigs from Hagerstown, Md., Winchester, Va., and Roswell, N. Mex.

Adults of this leafhopper are parasitized quite heavily by a species of the family Dryinidae. A rose leafhopper parasitized by a dryinid (Pl. V, D) is readily recognized by the distorted appearance of one of its wings under which the parasitic larva is noticed protruding

from the abdomen. Numerous parasitized leafhoppers were collected but no adult parasites were reared successfully.

A. Giard (24), in 1889, reported the dryinid *Aphelopus melaleucus* Dalm. and the pipunculid *Ateleneura spuria* Meig. as parasites of *Typhlocyba rosae* in France.

Among the predacious enemies of this insect, mites, spiders, and coccinellid and syrphid larvæ have been noted feeding on the nymphs to a limited extent.

Wilson and Childs (27), in 1915, recorded the larva of a green lacewing, *Chrysopa* sp., as preying on young nymphs in Oregon. The same authors list a dragonfly and a scatophagidfly as predacious enemies of adults.

REMEDIAL MEASURES.

The apple leafhopper, *Empoasca mali*, is one of the most difficult of all leafhoppers to combat successfully, especially because of the wide range of its food plants. In nurseries, however, this species confines its attack chiefly to the foliage of the apple, and if the hoppers can be reduced in sufficient numbers on this plant the danger of infestation from other host plants will be very small.

Little actual work has been done in dealing with the remedial measures to be used against this pest. One of the most frequently recommended methods which many writers have suggested as a means of controlling this leafhopper in nurseries is the use of sticky shields to catch the winged adults as they are jarred from the trees along the nursery row. The use of such a device has never proved satisfactory and it is impracticable when employed on a large scale.

Spraying with contact insecticides against the apple leafhopper has been generally advised. Weiss (19) suggested spraying with 1 pint of "black-leaf 40" to 100 gallons of Pyrox. But in general the recommendations have been so indefinite and vague that little value can be attached to them. In order to clear up the confusion which has existed in regard to the treatment for this insect, spraying experiments, based on the life-history studies, were carried out.

SPRAYING FOR THE FIRST BROOD.

Spraying experiments against the nymphs were conducted in the nursery of Hoopes Bros. & Thomas Co. at West Chester, Pa. Tests on a small scale were made, the spray being applied with a compressed-air sprayer and an angle nozzle at a pressure of 60 pounds. Larger plats were sprayed with a machine owned by the nursery which consisted of a double-acting hand pump capable of 100 pounds pressure and a 50-gallon galvanized tank set on a truck narrow enough to allow it to pass between two rows of trees. "Set nozzles" on an arrangement of pipes at the rear of this outfit were used, the nozzles

being so placed that it was possible to spray the undersides of the leaves of two rows of trees from both sides. It was necessary to use eight nozzles on this machine and consequently the pressure was greatly reduced.

Table XX indicates the results obtained with the compressed-air sprayer against the first-brood nymphs:

TABLE XX.—*Spraying experiments against the first-brood nymphs of the apple leaf-hopper, West Chester, Pa., 1916.*

Plat No.	Spray material.	Strength.	Date of application.	Number of trees treated.	Nymphs killed.
1	40 per cent nicotin sulphate and fish-oil soap.....	1-1,000	June 12	300	<i>Per cent.</i> 99
2	40 per cent nicotin sulphate and fish-oil soap.....	2-50	..do...	300	98
3	40 per cent nicotin sulphate.....	1-1,400	..do...	300	94
4	40 per cent nicotin sulphate lime-sulphur solution.....	1-1,500	..do...	300	99
5	Check; unsprayed.....	1½-50	.....	.....	0

It will be noted that good results were obtained on all plats of this experiment from the use of 40 per cent nicotin sulphate, though slightly better control was obtained when soap was added as a spreader.

The hand-power outfit with "set nozzles" was used in an experiment on several thousand 2-year-old trees which were heavily infested with first-brood nymphs.

The results are shown in Table XXIV.

TABLE XXI.—*Spraying experiments against the first-brood nymphs of the apple leaf-hopper, West Chester, Pa., 1916.*

Plat No.	Spray material.	Strength.	Date of application.	Number trees treated.	Nymphs killed.
1	40 per cent nicotin sulphate.....	1-1,400	June 15	4,000	<i>Per cent.</i> 92
2	..do.....	1-1,500	..do...	10,000	91
3	..do.....	1-1,600	..do...	4,000	89
4	40 per cent nicotin sulphate and fish-oil soap.....	1-1,500	June 16	13,000	97
5	Fish-oil soap.....	2-50	..do...	4,000	50
6	Kerosene emulsion.....	1-8	..do...	4,000	45
7	Check, unsprayed.....	5 per cent	..do...	.....	0

As will be noted, the best results in Table XXI were obtained on plat 4 where 40 per cent nicotin sulphate at a strength of 1-1,500 was combined with soap. The nicotin solution when used alone proved a little less effective than when the soap was added to the mixture as shown in plats 1, 2, and 3. A potash fish-oil soap solution at a strength of 1 pound of soap to 8 gallons of water (plat 5) gave poor results and was but little more valuable than a 5 per cent kerosene emulsion which was tried on plat 6.

During the spray application with "set nozzles" it was noted that the terminals of an occasional tree were missed by the spray. One reason for this was that the machine was top heavy and easily jolted when passing over a rough or stony place, and this resulted in the spray material being sent over the top of a tree. Furthermore, a few trees would outgrow the remainder of the trees in a row, so the spray material from the "set nozzles" would not reach the terminals of such trees. Nevertheless, sufficiently good results were obtained with the "set nozzles" to warrant their use.

TREATMENT FOR THE SECOND BROOD.

An attempt was made to destroy the second-brood nymphs by spraying and dipping upon trees which had received no treatment against the first brood. On the date of this experiment, July 18, the terminal leaves were so badly curled that the nymphs were well protected from the action of the spray. Four plats of about 700 trees were sprayed with a compressed-air sprayer, using 40 per cent nicotin sulphate at various strengths from 1-800 to 1-1,500 with soap added. The counts showed that only 2 per cent of the nymphs were killed on the best plats.

The dipping work was done with large shallow pans specially constructed for dipping leafhoppers and aphids on young nursery trees. The tops of the trees were thoroughly immersed in the pans of spray material. The same number of plats and the same insecticides that were used in the spray treatment above were tried in the dipping experiments. The results obtained by dipping were about the same as the spraying results, less than 2 per cent of the nymphs being killed.

Since such poor results were secured from spraying experiments against the second brood no effort was made to spray the third-brood nymphs, for at the time of the presence of the latter on unsprayed trees the terminals are even further curled and inaccessible to a spray liquid.

METHODS AND TIME OF APPLICATION.

Attempts to control the winged adults of leafhoppers by spraying have always proved futile because of the agility of movement of the full-grown insects and because of their immunity to the action of a spray liquid at this stage. This has been demonstrated by previous investigators in the case of the apple leafhopper as well as in the case of other leafhoppers of economic importance.

A spray treatment to be effective must be applied when the insects are in the nymphal stages. The proper time to spray against the apple leafhopper is at the time when a large number of the first-brood nymphs have attained the third stage of development. For the

seasons of 1915 and 1916 at West Chester, Pa., this date was between June 10 and June 20. It is not safe to delay the application until the end of the nymphal period, since by that time the insects will have produced sufficient injury to cause the tender terminal leaves to curl, and the result is that the nymphs on the curled leaves will be protected against the spray.

The nymphs feed on the undersides of the terminal leaves during the entire nymphal period, so the spray material must be directed in such a manner as to wet the underside of the leaves thoroughly. Special care must be taken to see that the foliage of the upper half of the trees and especially the terminals are well sprayed. If a machine with "set nozzles" is used, the lower nozzles should be placed at an angle that will insure a thorough spraying of the lower surfaces of the leaves.

TREATMENT FOR THE ROSE LEAFHOPPER.

The injury caused by the rose leafhopper on nursery apple trees is seldom serious enough to warrant a special spray application. This species confines its attack to the undersides of the leaves of the lower half of the trees and the injury is characterized by mottled white or yellowish spots on the foliage. As a result of continued feeding some defoliation takes place which reduces the vitality of the trees slightly.

Whenever necessary, this species can be controlled by one spray application of a tobacco insecticide against the first-brood nymphs. A spraying of $\frac{1}{4}$ pint of 40 per cent nicotin sulphate to each 50 gallons of water with the addition of 2 pounds of soap, made at the time when the maximum number of nymphs are present on the foliage, will give satisfactory results. The most effective time to make this application is when the greatest number of nymphs have reached the third stage, which is three to four weeks earlier than the date for the spraying against the first-brood nymphs of the apple leafhopper. For southeastern Pennsylvania the correct time for spraying the rose leafhopper during the seasons of 1915 and 1916 was from May 15 to May 25.

RECOMMENDATIONS.

The apple leafhopper can be controlled by spraying against the first-brood nymphs with a tobacco insecticide. A 40-per cent nicotin sulphate solution at the rate of 1-1,500 to which 2 pounds of soap is added to each 50 gallons will so reduce their numbers that injury to the growth of the trees by the later broods will not be serious. When it is desirable to use lime-sulphur solution with the tobacco insecticide, soap must be omitted to prevent burning. The spray should be directed upward so as to wet the underside of the leaves, and par-

ticular attention should be paid to wetting every terminal leaf thoroughly. The application should be made when the majority of the nymphs are in the third stage, which occurs about three weeks after the first nymphs are found in the terminal leaves.

The rose leafhopper is far less injurious to the foliage of nursery applestock than the apple leafhopper. Should the infestation by rose leafhoppers be heavy enough to justify spraying, the same remedial treatment recommended for the apple leafhopper can be used, except that the application should be made three or four weeks earlier than the one for the latter insect.

SUMMARY.

The apple leafhopper, *Empoasca mali*, causes serious injury to apple nursery stock by extracting the plant juices from the terminal leaves; as a consequence the leaves curl, become undersized, and fail to function normally, thereby retarding the growth of the trees. The injury is produced by the feeding of both nymphs and adults. In southern Pennsylvania this species is three-brooded and hibernates only in the adult stage. Eggs are laid within the leaf tissue on the underside of the leaves. This leafhopper is widely distributed over the United States and attacks a great variety of host plants.

In literature the above species has been confused with another leafhopper which attacks the foliage of nursery apple trees, namely, the rose leafhopper, *Empoa rosae*. The latter insect is two-brooded and winter is passed in the egg stage. Winter eggs are deposited under the bark of apple trees. These eggs hatch about a month earlier in the spring than eggs deposited by overwintered females of the former species.

The rose leafhopper may be distinguished from the apple leafhopper by its lighter color and by the absence of the six or eight white spots present on the frontal margin of the pronotum of the latter species. Differentiation between the nymphs of the two species is more difficult. The distinct types of injury produced by the two insects, however, is a ready means of distinguishing them. The rose leafhopper feeds on the lower leaves and produces white or yellow spots on them while the other species attacks the terminal leaves, curls them, and stunts the growth of the trees.

Parasites seem to play a far more important rôle in reducing the numbers of the rose leafhopper than they do in reducing the numbers of the more injurious apple leafhopper. Larvæ of dryinid parasites are quite common on the adults of the former while only rarely have they been found attacking the latter. *Anagrus epos* Girault and *Anagrus armatus* Ashm. var. *nigriventris* Girault, parasites of the winter egg of the rose leafhopper, help considerably in checking the num-

bers of this species. No parasites have been reared from eggs of the apple leafhopper.

A single spraying with 40 per cent nicotin sulphate at the rate of 1-1,500 combined with soap will so materially check an infestation by the apple leafhopper when applied against the first-brood nymphs that injury caused later by those that escape will be of little consequence. The same treatment made three or four weeks earlier is effective against the rose leafhopper, though this species is seldom injurious enough to justify a special application.

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PROFESSIONAL PAPER

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THE BROAD-BEAN WEEVIL.

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INTRODUCTION.

The growing of broad or horse beans in California during the last few years has been seriously handicapped everywhere by the presence of the broad-bean weevil (*Bruchus rufimanus* Boh.). The practical impossibility of growing uninfested beans caused the early abandonment of a considerable acreage. The greatest abandonment, however, followed the ruling, according to the Federal Food and Drugs Act, that weevil-infested broad beans are adulterated food, and that their shipment was prohibited in interstate commerce.

The Bureau of Chemistry first ruled that beans infested "to any material extent" could not be shipped (4),¹ but later changed the ruling to allow shipment to any lot which contained "not more than 15 per cent of wormy or weevil-infested beans" (5). The 15 per cent limit is tentative only. Acting under this ruling, a shipment of broad beans from a San Francisco broker was seized in New York, after having been found to be over 25 per cent infested. The broker was tried for violating the Food and Drugs Act, convicted

¹ Numbers in parentheses refer to "Literature cited," p. 22.

by a jury, and fined \$150 (9). Since then many dealers have refused to handle horse beans, while those who continued to deal in them have had to exercise caution that no shipment contained more than 15 per cent infested beans, or else run the risk of confiscation. The numerous confiscations during the past few years of shipments in transit by food inspectors, and the cost of hand picking to keep the infestation within the 15 per cent permitted, has resulted in keeping the price of beans low and reducing the acreage.

Although the bean is commonly called the horse bean, the name is somewhat a misnomer, as only about 30 or 40 per cent of the crop is used as stock feed. The larger portion is shipped to New York and other eastern cities, where it is used for food by Italians and Portuguese, and is known as fava. Other names are English bean, Windsor bean, and tick bean.

The horse bean is used also as a green vegetable, and of late years has been planted to a considerable extent as a winter cover crop, especially in fruit orchards. A recent Farmers' Bulletin (8) recommends further plantings along the Pacific coast, the Gulf of Mexico, and the South Atlantic States, not only for the dry beans for human consumption, but also for the green vegetable, stock feed, and green manuring.



FIG. 1.—The broad-bean weevil: Egg. Greatly enlarged. (Chittenden.)

DESCRIPTION.

THE EGG.

The egg (fig. 1) is elliptical-ovate, about twice as long as wide, a trifle more pointed anteriorly, its surface smooth with no visible sculpture. When first laid it is whitish and glistening, but gradually turns darker. Just before hatching, the black head of the embryo can be seen plainly through the shell.

THE LARVA.

The young larva is pale yellow, with dark or black head and mouth-parts. The full-grown larva is cream colored, with small brown head and black mouth-parts. It is 4.5 to 5.5 mm. long and 2.5 to 3 mm. wide.

THE PUPA.

The pupa when first formed is light yellow or cream colored, with legs and wing-covers whiter. It gradually turns darker, particularly the appendages, until it is light brown before transforming. It measures about 3 mm. wide and 5 mm. long.

THE ADULT.

The adult (fig. 2) is from 3.5 to 4.5 mm. long and a little over half as wide. The general color is black, with white markings on the elytra and pygidium, giving it a somewhat mottled grayish appearance. The head is dark. The basal four joints of the antennæ are reddish brown, the remainder black. The forelegs are reddish brown and black, while the middle and hind pairs are black.

The species closely resembles the pea weevil (*B. pisorum* L., fig. 3), but may be separated by the following characters:

Posterior femora acutely dentate; thorax broad; pattern of elytra well defined; pygidium with a pair of distinct apical black spots-----*pisorum* L.
 Posterior femora obtusely or obsolete dentate; thorax narrow; pattern of elytra more or less suffused; pygidium with black apical spots lacking or illy defined-----*rufimanus* Boh.



FIG. 2.—The broad-bean weevil (*Bruchus rufimanus*): Adult or beetle. Enlarged. (Chittenden.)

SYNONYMY.

Bruchus rufimanus Boheman.

Bruchus rufimanus Schoenherr, Gen. et Spec. Curculionidum, v. 1, p. 58, 1833.
Bruchus granarius auct. (not L.) Westwood, Curtis, Ormerod, Wood, Riley, Fletcher, Lintner, et al.

Mylabris rufimana Boh., Baudi, Deutsch. Ent. Zeitschr., 1880, p. 404.

The *Bruchus granarius* L. is *Laria atomaria* L., Syst. Nat., 12th ed., p. 605, 1776-1778.

RECORDS OF OCCURRENCE IN CALIFORNIA.

Although horse beans were grown in California as early as 1887, the horse-bean weevil was not recorded as ac-

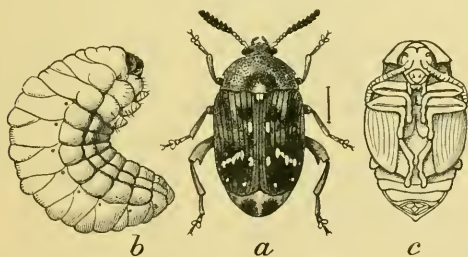


FIG. 3.—The pea weevil (*Bruchus pisorum*): a, Beetle; b, larva; c, pupa. Enlarged. (Chittenden.)

tually established in the United States until September 18, 1909. On that date Mr. I. J. Condit, then collaborator of the Bureau of Entomology, collected live specimens at San Luis Obispo, on growing horse beans (2, 3). Inquiry by the writer among buyers and growers indicates that the weevil was established in California many years before 1909. Mr. P. G. Hammer, San Francisco, writes as follows, "We are quite positive of the date, for in our dealing with this variety of beans the first indication of weevil infestation appeared possibly not later

than 1888," from Alameda County. One other broker gives 1893 as the first date infested beans were observed by him from the same locality. Mr. E. A. Bunker, from a personal transaction in 1898, positively remembers that date as the first year infested horse beans were observed by him. Other dates for the different localities given by different bean brokers are as follows: Gilroy, 1890; Watsonville, 1900; Morro, 1900; Oceano, 1903; Halfmoon, 1904; and Sacramento, 1908.

It must be remembered that in none of the above dates were the weevils in horse beans identified as *Bruchus rufimanus*, but there is little doubt that this is what they were. It is, therefore, quite evident that the insect was present in the different localities a number of years before September, 1909.

DISTRIBUTION IN CALIFORNIA.

The principal broad-bean sections in California are around San Francisco Bay and down along the coast to a little below San Luis Obispo. The insect is distributed all over this section, having been taken or reported from the following counties: Sonoma, Napa, Yolo, Sacramento, San Joaquin, San Mateo, Alameda, Santa Cruz, Santa Clara, San Benito, Monterey, and San Luis Obispo (fig. 4). Broad beans are grown in small quantities in many other counties, usually in back yard gardens or in small plots for the green beans. Of late years, in several counties, they have been quite extensively planted as cover crops, particularly in citrus orchards. Unless great care is exercised, which is not often done, in planting uninfested or treated seed, it is safe to say that the broad-bean weevil will be found wherever broad beans are grown and allowed to come to maturity. The writer has found eggs on the green pods of broad beans planted for cover crops in Los Angeles, Orange, and Riverside counties. Cover crops, however, are all plowed under before the weevil has had a chance to develop.

SPREAD IN CALIFORNIA.

The broad-bean weevil probably became established in Alameda County, where horse beans were first grown, about 1888. It next appeared in Santa Clara County in 1890, and in Santa Cruz, Santa Clara, and San Luis Obispo Counties in 1900. By 1904 it was reported from San Mateo County; by 1911 from Sacramento and Sonoma, by 1914 from Yolo and San Benito, by 1916 from San Joaquin, and by 1917 from Napa.

DISSEMINATION.

Although the adult insect is an active creature and doubtless can fly some little distance, from one field to another, or from where beans may be stored to a near-by field, the principal method of dis-

semination is through the transportation from one locality to another of beans infested with live weevils. It is possible for the adults to escape both after the beans have reached their destination and while they are en route. Planting of these infested beans in a new locality is bound to result in an infested crop.

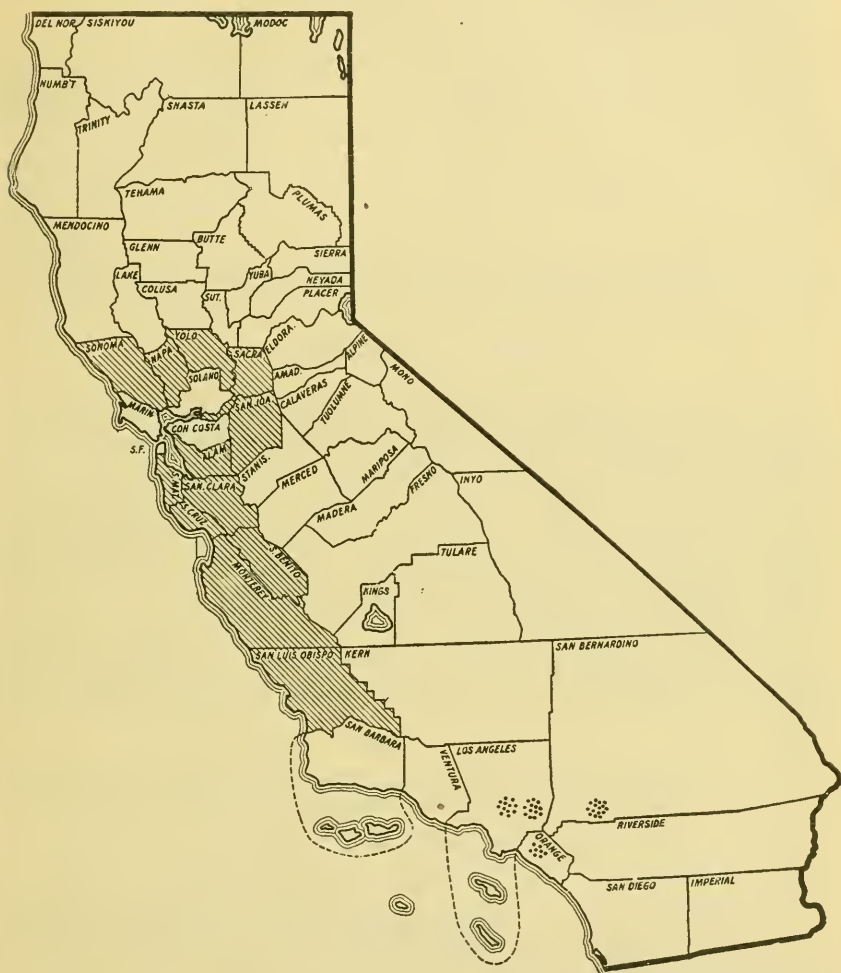


FIG. 4.—Map of California, showing counties from which the broad-bean weevil has been taken or reported.

NATURE OF DAMAGE.

Damage caused by the broad-bean weevil is principally due to the fact that the larva feeds and transforms to the adult within the beans (Pl. I, fig. 3, *a*, *b*). Many adults remain in the beans for several months, and their presence renders the beans unfit for food. Some adults emerge soon after forming, leaving round holes in the

beans where the tissue was consumed by the larvæ (Pl. I, figs. 4, *a*, *b*, and 5). This "buggy" appearance lessens the salability of the beans. Infested beans are not only reduced somewhat in weight (see Table I) but their germinating power is also lessened, as will be shown later on.

TABLE I.—*Showing amount of beans consumed by the broad-bean weevil.*

Number of weevils in beans.	Weight of 50 beans.	Weight consumed.	Percentage consumed.
None.....	<i>Grams.</i> 76,970	<i>Grams.</i> .....	.....
1.....	74,800	2,170	2.81
2.....	72,430	4,540	5.89
3.....	70,150	6,820	8.86

This table shows that approximately 3 per cent of the weight of a bean is consumed by the larva of each weevil developing in it.

EXTENT OF DAMAGE.

It is estimated that the area devoted to broad beans commercially is at present about 3,000 acres for the dry beans, 100 acres for canning green, and 1,000 acres for cover crops. In addition many hundreds of acres are grown in small lots, back-yard gardens, etc., for home consumption. The commercial production of dry beans for market is at present about 50,000 bags, but has been, before weevil damage became so general, as much as 200,000 bags.

After a careful survey of the 1916, 1917, and 1918 crops of horse beans, and of numerous samples taken by food inspectors of the Bureau of Chemistry and the writer. Tables II and III were prepared.

TABLE II.—*Summary of the percentage of infestation of the 1916, 1917, and 1918 crops of broad beans grown in California.*

Infestation.	1916 crop.		1917 crop.		1918 crop.	
	Number of bags.	Per cent of total crop.	Number of bags.	Per cent of total crop.	Number of bags.	Per cent of total crop.
0 to 5 per cent.....	18,851	38.10	15,372	46.46	6,638	26.75
5.1 to 10 per cent.....	8,366	16.88	6,855	20.71	5,341	16.16
10.1 to 15 per cent.....	6,835	13.81	4,904	14.82	4,629	14.01
15.1 to 30 per cent.....	11,114	22.46	4,852	14.66	10,547	31.93
Above 30 per cent.....	4,318	8.75	1,107	3.35	3,681	11.15
Total.....	49,474	100.00	33,090	100.00	33,036	100.00

The damage according to the different horse-bean regions is shown in the following table:

TABLE III.—*Summary of the 1916, 1917, and 1918 crops of broad beans showing the percentage of weevil infestation by localities.*

	1916 infesta- tion.	1917 infesta- tion.	1918 infesta- tion.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Sacramento:			
Maximum.....	41	63	84.3
Minimum.....	0	0	1
Average.....	9.09	12.7	22.4
Oceano-Morro:			
Maximum.....	50	63	17.2
Minimum.....	0	0	0
Average.....	14.5	14.5	2.92
Halfmoon:			
Maximum.....	55	56.6	56
Minimum.....	0	.5	0
Average.....	13.6	10.9	16.8
Gilroy:			
Maximum.....	70	46	.....
Minimum.....	0	1	.....
Average.....	24	16	.....

Table II shows that of the entire crop of broad beans for the three years 1916, 1917, and 1918, 31.21, 18.01, and 43.08 per cent, respectively, were above the 15 per cent limit of weevil infestation allowed by the Bureau of Chemistry, and therefore could not be shipped unless hand picked. Table III shows that even the average percentage of infestation for the entire 1916 crop in the Halfmoon and Gilroy regions was above the 15 per cent limit, while the same is true of the Sacramento and Halfmoon districts for the 1918 crop. This table also shows some interesting data on the increase in infestation. Sacramento is a comparatively new district for raising broad beans, and at first the weevil infestation was low, but as planting continued from year to year, and the acreage increased, the percentage of infestation greatly increased, going from a maximum of 41 per cent in 1916 to 63 per cent in 1917 and 84.3 per cent in 1918, while the average percentage of infestation for the same years increased from 9.19 to 12.7, and then to 22.4 per cent. Climatic conditions at Sacramento are adverse to late planting, and early planting as practiced there is favorable to heavy weevil infestation. Unless control measures are practiced, and only uninfested or treated seed is planted, this district soon will be in the same position in regard to the production of horse beans that Alameda County has been in for some years. The low percentage of infestation in the Oceano-Morro district for the year 1918 will be explained later.

Estimates from bean brokers on the reduction in value of broad beans from the infestation of the weevil vary from 25 per cent to total unsalability, depending on the degree of infestation.

The cost of hand picking to remove the weevily beans also depends on the degree of infestation, but it is estimated at about \$1.50 per 100 pounds.

Estimates of the reduction on the total horse bean acreage, because of the increase in weevil infestation, range from 25 to 75 per cent. Alameda County was formerly the largest producer, but at present, due largely to the extensive infestation of all horse beans grown there, practically no beans are produced commercially. It is also estimated that if weevil infestation could be prevented, the acreage for the dry-bean crop alone would be increased from 100 to 300 per cent in that county.

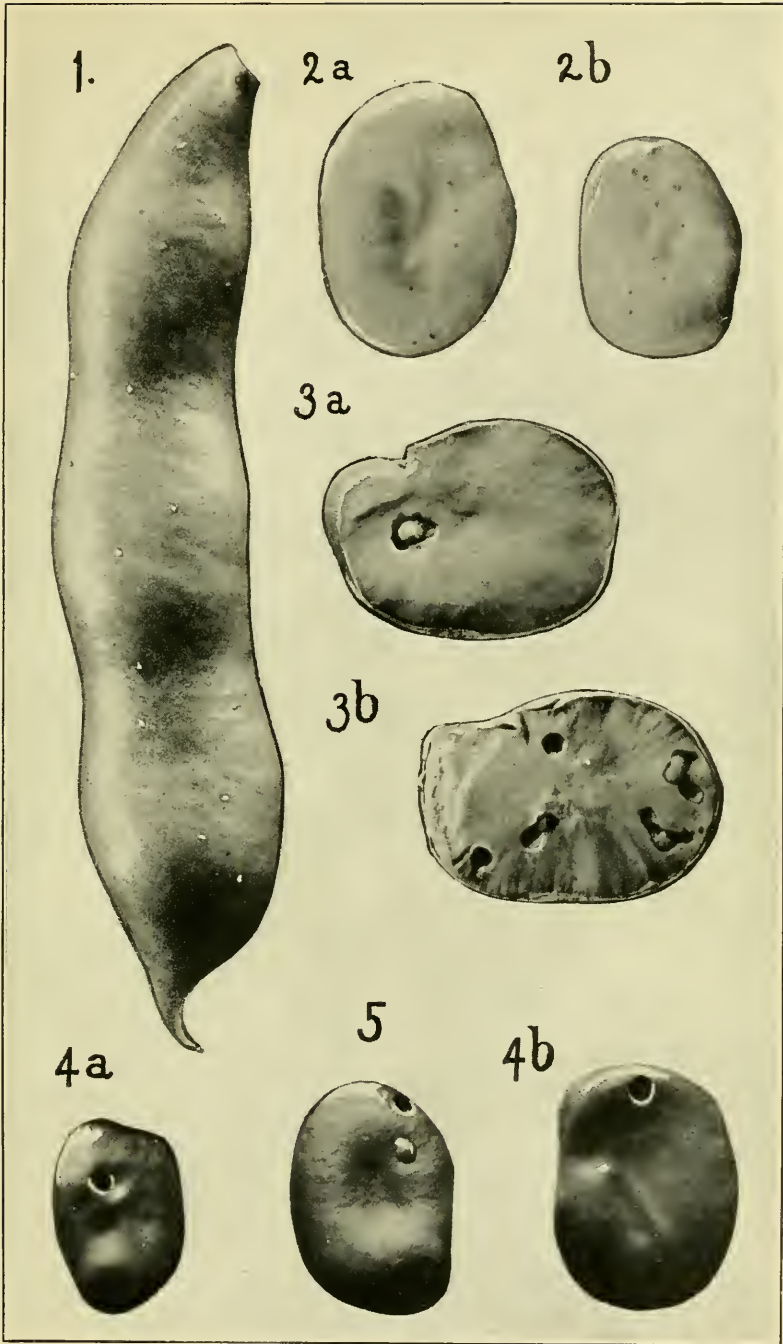
It will be seen from Table III that there is considerable variation in the percentage of infestation in the different districts. There is also great variation in the number of weevils developing in a single bean. In the case of the pea weevil *B. pisorum* (fig. 3), with a very similar appearance and life history, only one weevil develops in a seed, but with the broad-bean weevil there are often two and three adults in a single bean, while it is not at all rare to find four, five, and even six. The following table illustrates this:

TABLE IV.—Summary of the percentage of broad beans infested with different number of weevils.

Number beans examined.	Locality raised.	Year raised.	Number weevils per bean.	1 weevil per bean.	2 weevils per bean.	3 weevils per bean.	4 and 5 weevils per bean.	Total per cent infested.
1,000.....	Hayward....	1915	371	367	186	63	13	62.9
1,000.....	do.....	1916	331	324	216	95	34	66.9
1,000.....	do.....	1917	781	164	46	9	0	21.9
1,000.....	Stockton....	1917	880	105	14	1	0	12
1,000.....	Hayward....	1917	573	227	140	29	31	42.7
Average..... per cent..	.....	.....	58.9	23.7	12	3.9	1.5	41.1

LIFE HISTORY.

The eggs are laid on the outside of the green pods, being cemented to the latter by a glutinous secretion. They are laid singly and indiscriminately over the surface of the pods (see Pl. I, fig. 1) without apparent reference as to whether the position is favorable or unfavorable to the newly hatched larva getting into the young bean. The number of eggs on a pod also bears no relation to the number of beans it contains, as often the former exceeds by many times the number of larvæ which might develop therein. One pod 4 inches long was observed with 55 eggs deposited on it. The following table shows the variation in number of eggs laid on a pod.



THE BROAD-BEAN WEEVIL.

1, Broad-bean pod showing eggs laid upon its surface; 2, broad beans showing entrance holes or "stings" of larvæ; 3, a, b, broad beans cut open to expose larvæ of the broad-bean weevil and the damage they have done; 4, 5, infested broad beans showing emergence holes made by adult weevils in leaving the seed. In figure 5, below the emergence hole, is shown a "window."

TABLE V.—*Number of eggs of Bruchus rufimanus deposited on pods at Hayward, Calif.*

Date.	Number pods on plant.	Total number eggs per plant.	Number eggs per pod.		
			Maximum.	Minimum.	Average.
1916.					
April 20.	12	88	17	2	7.3
Do.	19	153	17	1	8
April 25.	5	30	18	2	6
Do.	12	70	29	1	5.8
Do.	14	119	22	1	8.5
Do.	8	71	19	4	8.8
Do.	8	48	9	3	6
Do.	11	115	23	2	11.3
Do.	10	144	42	8	14

No eggs were observed by the writer except on the pods, the latter varying in size from less than an inch to full growth of 5 inches. Most of the eggs are found on the larger pods.

Although adults have been noticed a number of times crawling over the plants during the day, the act of oviposition was never observed. It is probable that it occurs late in the evening or at night.

Efforts to induce oviposition in captivity were not successful, so the total number of eggs laid by individual females was not ascertained.

The duration of the egg stage was found to be from 9 to 18 days, with an average of 13 days. A few days before hatching the dark head of the embryonic larva can be seen plainly through the egg-shell. The larva draws its head back, leaving about one-quarter of the shell hollow. For about a day the position appears to be unchanged, then gradually as the larva eats through the side of the shell attached to the pod and into the pod the clear space in the shell becomes larger until the latter is entirely empty, having a glassy and transparent appearance. It usually takes about two days from the time the larva begins eating through the shell until it is entirely out of the latter and into the bean pod.

The young larva begins feeding when the bean is green, and it is well along toward maturity before the bean dries up. The amount of food consumed is small compared with what other insects eat. It appears that the young larva often eats out a short tunnel, advancing a little distance from the point where it entered the bean. When the larva gets larger it eats out a hole somewhat its own shape, and about 50 per cent larger, as is shown in Plate I, figure 3, *a* and *b*.

When the larva reaches maturity, and just before pupating, it eats out a round hole in the cotyledon, directly under the epidermis. The hole is plainly seen through the half-transparent skin or "window," which is broken easily by the adult weevil when it is ready to emerge (see upper beans in Pl. I, fig. 5). The hole is seldom at the spot where the larva entered, but at varying distances from it. The

point where the young larva entered, sometimes called the "sting," plainly shows on the dry bean as a dark spot varying in size from a pinpoint to almost as large as a pinhead. This is illustrated in Plate I, figure 2, *a* and *b*.

Mortality among the larvæ after entering the beans is rather high. This is so both in the case where by far more larvæ enter a bean than could develop in it, and in the case where only one or two larvæ enter, although the percentage of mortality is less with the latter than with the former. Table VI graphically illustrates this point:

TABLE VI.—*Comparison of the number of larvæ of Bruchus rufimanus entering beans with the number reaching maturity.*

Number of beans.	Number of larvæ entering beans.	Number of adults.	Maximum number of larvæ entering a bean.	Average number of larvæ entering a bean.	Average number reaching maturity.	Percentage of larvæ entering beans reaching maturity.	Percentage of beans entered by larva.	Percentage of beans infested with adults.
100.....	263	132	10	2.63	1.32	50.1	85	70
100.....	199	95	7	1.99	.95	47.7	78	63
100.....	226	86	16	2.26	.86	38	80	58
100.....	72	16	9	.72	.16	22.2	40	15
100.....	54	29	5	.54	.29	53.6	39	26
Average.....	162.4	71.6	9.4	1.62	.71	42.3	64.4	46.4

It will be seen from the table that although as many as 16 larvæ may enter a single bean, the average number is about 2, and a total average of a little over 40 per cent reach maturity. Comparison with Table IV shows that while a maximum of from 5 to 16 larvæ may enter a bean, the percentage of beans containing more than 2 adults is small.

The larval stage is from 10 to 15 weeks, the average being about 12 weeks.

Immediately after eating out the round hole in the cotyledon, already referred to, the full-grown larva becomes quiet, and in a short time pupates. At first the pupa is the same color as the larva, but gradually turns darker until it is a dark brown.

The pupal stage is from 7 to 16 days with an average of 10 days.

When the adult is first formed it is light brown and very soft, but it gradually turns darker and becomes harder. The adult may soon eat its way out of the bean through the "window" prepared by the larva, or it may remain in the bean for several months. In fact many adults never emerge from the beans at all, but die in them. If the weather is warm, or the beans are handled much, the weevils are apt to emerge from the beans sooner and in greater numbers than if the weather is cool and the beans are not handled much. Many of the adults emerge from the beans after the latter have been planted. The duration of the adult stage varies considerably, de-

pending on the weather conditions, from one month to a possible eight months. Table VII gives a summary of the life-history records.

TABLE VII.—*Life history of the broad-bean weevil in California.*

Locality.	Eggs laid.	Hatched.	Duration of egg stage.	Pupated.	Duration of larva stage.	Adult.	Duration of pupa stage.	Died.	Duration of adult stage.	Total length of life.
	1917.	1917.	Days.	1917.	Days.	1917.	Days.		Days.	Days.
Pasadena.	May 3	May 15	12	Aug. 19	96	Aug. 27	8	Sept. 27, 1917	31	147
Hayward.	May 11	May 24	13	Aug. 29	98	Sept. 8	10	Feb. 8, 1918	152	273
Hayward.				Sept. 3		Sept. 12	9	Dec. 7, 1917	86	.....
Alhambra.	1918.	1918.		1918.		1918.				
Alhambra.	Apr. 9			July 26		Aug. 4	10			
Alhambra.	..do.			Aug. 5		Aug. 21	16			
Alhambra.	..do.			Aug. 22		Aug. 30	8			
Alhambra.	Apr. 28	May 5	9	Aug. 5	90	Aug. 12	7	Apr. 23, 1919 ¹	253	359
Alhambra.	May 6	May 17	11	..do.	80	..do.	7	Dec. 26, 1918	137	235
Alhambra.	May 7	May 20	13	Aug. 22	94	Aug. 30	8	May 31, 1919 ¹	274	393
Alhambra.	Apr. 28	May 7	9	Aug. 12	97	Aug. 28	16			
Alhambra.	May 17	May 27	10	Sept. 10	106	Sept. 17	7			
Alhambra.	May 17	June 2	16	Aug. 5	64	Aug. 13	8	Dec. 6, 1918	114	203
Alhambra.	May 17	June 4	18	Aug. 30	87	Sept. 13	14	Nov. 30, 1918	78	197
Alhambra.	Mar. 14	Mar. 28	14							
Averages.			12.5		90		10		140	258

¹ Theoretical, showing possible life history from two records.

SEASONAL HISTORY.

Egg laying begins about the middle of March, is heaviest in April, and extends a little beyond the middle of May. The larval period is from the latter part of March to the middle of October. Pupæ can be found from the first of August to the latter part of October, and adults from the middle of August to about the following June. Tables VIII and IX show the actual records of the seasonal history for 1917 and 1918.

TABLE VIII.—*Seasonal history of Bruchus rufimanus in Pasadena and Alhambra, Calif.*

Year.	First eggs observed.	Last eggs observed.	First eggs hatched.	Last eggs hatched.	First full-grown larvæ.	Last full-grown larvæ.	First pupa.	Last pupa.	First adult.	Last adult.
1917.....	Mar. 23	May 20	.....	.....	Aug. 1	Oct. 19	Aug. 3	Oct. 22	Aug. 10	
1918.....	Mar. 14	May 19	Mar. 28	June 4	July 16	Sept. 26	July 18	Sept. 28	July 25	(¹)

¹ About June 1, 1918.

TABLE IX.—Graphic chart of life history of *Bruchus rufimanus* for seasons of 1917-18 and 1918-19.

Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	Eggs,	-----	-----	-----							
	Larvæ,	-----	-----	-----	-----	-----	-----	-----	-----		
	Pupæ,						-----	-----	-----		
	Adults,						-----	-----	-----	-----	-----

Continuous line=1917-18. Broken line=1918-19.

Although a few adults may be found as late as June, the majority die before the end of March. During 1917 a number of badly infested beans were inclosed in a box. Ten per cent of the weevils were dead by February 1, 50 per cent by March, and 90 per cent by the 1st of April. A very few remained alive until June. The results of field observations at Hayward during 1918 as to the prevalence of weevils in the fields are recorded in figure 5. Each count represents an examination of horse-bean plants for a period of 15 minutes.

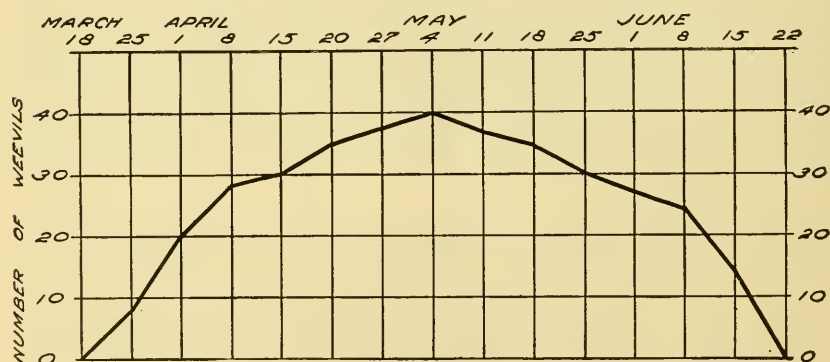


FIG. 5.—Curve showing abundance of broad-bean weevils in a field at Hayward, Calif., 1918.

Adults have never been observed in the field before the latter part of March, but it is evident that some of them must live through the winter, hiding in the soil, or among rubbish, leaves, etc. In experimental plantings of infested beans, both in the fields and in pots, live adults have been observed to come out of the soil several days after planting. In one case a germinating bean was dug up two weeks after it had been planted, and a live weevil, which had emerged from the bean, was found clinging to it. In another germination

test, beans were taken from pots 20 days after planting, and a live adult found in one of its burrows in a bean that had germinated.

When disturbed, the weevils have the habit of folding their legs tightly and feigning death. On the plant they will fall to the ground, but quickly become active. In the sack or on a table they are apt to remain quiet, "playing possum" for some time, and it takes quite a prod with a pencil or pin to make them become active.

GERMINATION TESTS OF INFESTED BEANS.

A number of tests were made to determine the effect of weevil infestation on the germinating power of the beans and at the same time compare new seed and that held over a year.

TABLE X.—*Germination tests of infested and noninfested beans; new and year-old seeds.*

Date.	New crop seed, percentage of germination—					Date.	Old crop seed, percentage of germination—				
	With no weevil.	With 1 weevil.	With 2 weevils.	With 3 weevils.	With 4 and 5 weevils.		With no weevil.	With 1 weevil.	With 2 weevils.	With 3 weevils.	With 4 and 5 weevils.
Apr. 26, 1916.....	98	90	60	72	.....	Oct. 27, 1916.....	96	94	86	88	.....
Nov. 20, 1916.....	98	92	68	98	.....	Nov. 20, 1916.....	100	90	90	90	75
Dec. 1, 1916.....	96	94	86	88	.....	Dec. 1, 1916.....	90	70	90	90	.....
Dec. 13, 1916.....	86	60	54	50	.....	Dec. 13, 1916.....	88	64	56	.....	.....
May 8, 1916.....	100	100	92	92	87	Mar. 22, 1918.....	84	72	80	24	44
Mar. 22, 1918.....	92	88	88	73	.....	Oct. 17, 1918.....	100	38	54	8	.....
Oct. 17, 1918.....	98	68	26	28	52						
Apr. 28, 1916.....	98	90	88	68	70						
Average.....	95.7	82.7	72.7	71.1	69.6	Average.....	93	71.1	76	60	59
Average of infested beans..... 74						Average of infested beans..... 66					

This table shows that as the number of insects per bean increases, the percentage of germination decreases. The drop is about 20 per cent from perfect beans to those infested with one weevil, and somewhat less for each weevil up to the maximum of 4 and 5 weevils, which gives a germination of 60 or 70 per cent. The table also shows that the percentage of germination is a little more with new crop seeds than with those held over for a year.

The table, however, does not show the reason for the low germination in the infested beans. In only a few cases does the insect actually injure the embryo or germ, but by far the greatest damage comes from the fact that the holes made by the insects allow bacteria or fungi to enter, which cause the beans to rot. In a number of cases rotting takes place soon enough to prevent germination entirely, but a large number of beans are killed also after the seed has actually germinated, and before the shoot can get out of the ground. Rotting of the seed is much worse during cool or cold weather, when germi-

nation is slow, than during warm weather, when germination takes only a few days. One germination experiment had to be discarded, as rotting of the seed was practically 100 per cent. In another test, the soil was sterilized with formalin, and germination was perfect, not only with uninjured beans, but also with those having 1, 2, and 3 weevils in them. Those having 4 and 5 weevils gave a 92 per cent germination, the balance being injured in, or too close to, the germ.

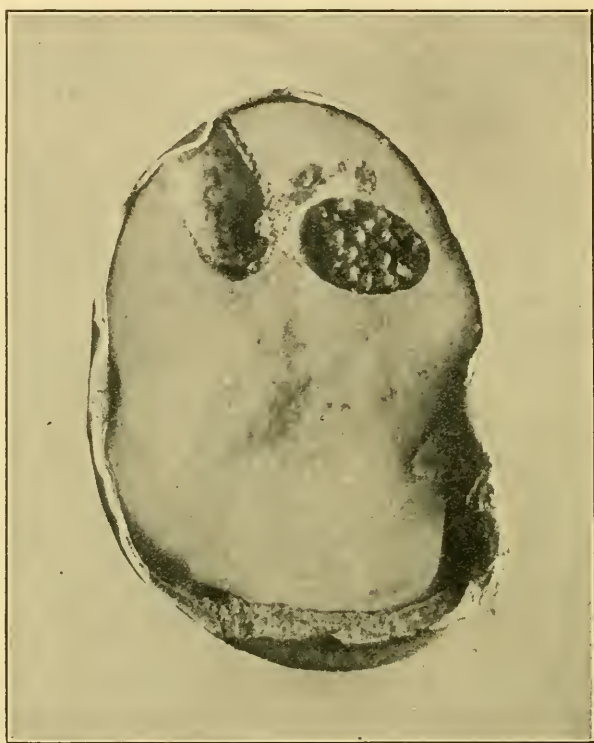


FIG. 6.—Broad bean cut in half to show pupal cell of the broad-bean weevil containing predacious mite (*Pediculoides ventricosus*). Enlarged. (Chittenden.)

Whether infested beans produce weak plants or small crops, was not determined, but it was observed many times that the sprouts from infested beans were much less vigorous than those from perfect beans.

NATURAL ENEMIES.

The only natural enemy of *Bruchus rufimanus* observed during the investigation was a predacious mite, *Pediculoides ventricosus* Newport (fig. 6). This was observed a number of times, but only a small fraction of 1 per cent of the insects were affected. Mr. W. B. Parker reports having observed a beetle in the clutches of the

ruduviid bug *Zelus renardii* Kolen. Several hymenopterous parasites¹ are recorded by European writers, but have not been observed in this country.

CONTROL MEASURES.

It is obviously impossible, at least from a practical standpoint, to prevent infestation of the beans in the field by such methods as the application of poisons or deterrents. Any control measures, therefore, must be toward keeping the adults from getting into the fields, or, in other words, must consist of planting seed which contains no live weevils.

Mr. W. B. Parker reports good success in treating infested beans with water heated to about 150° F. (160° and over affects germination) for from 15 to 20 minutes. This might do for small gardens, but is obviously impractical for commercial plantings.

DRY HEAT.

A series of experiments was carried on to determine the degree of heat and the length of time required to kill the weevils. Preliminary experiments showed that exposing infested beans to from 120° to 160° F. for from 5 to 40 minutes did not kill all the weevils. Following is the result of the final experiment. Heat was supplied by electricity. For each test a sack of about 2 pounds of beans was used in a fumigating box with a capacity of 60 cubic feet. Later the beans were carefully examined to find whether they contained live or dead weevils.

TABLE XI.—Effect of dry heat on the broad-bean weevil.

Date treated.	Date examined.	° F.	Time treated.	Result.
1917.	1918.		Minutes.	
Nov. 15.....	Mar. 28.....	160	30	Some alive.
Oct. 24.....	do.....	160	40	Do.
Oct. 20.....	do.....	160	40	Do.
Nov. 15.....	do.....	170	20	Do.
Oct. 24.....	Mar. 5.....	170	20	Do.
Do.....	Mar. 28.....	170	25	All dead.
Oct. 20.....	do.....	170	30	Do.
Nov. 15.....	do.....	170	30	Some alive.
Oct. 20.....	Mar. 5.....	170	40	All dead.
Nov. 15.....	Mar. 28.....	180	15	Some alive.
Do.....	Mar. 5.....	180	20	All dead.
Aug. 24.....	Mar. 28.....	180	20	Some alive.
Sept. 19.....	do.....	180	30	Do.
Oct. 24.....	Feb. 27.....	180	30	All dead.
Oct. 20.....	Mar. 28.....	180	40	Do.

These experiments indicate that dry heat is not a satisfactory remedy for the broad-bean weevil, because in order to be effective it has to be so high that the germinating power of the beans may be

¹ *Sigalphus pallipes* Nees, *Sigalphus thoracicus* Curt., *Chremylus rubiginosus* Nees (1, p. 57).

destroyed. The experiments were carried on mostly in the fall, shortly after all the adults had formed. Other experiments during the spring, toward the end of the life of most of the weevils, gave a complete killing with a lower degree of heat and a shorter time.

Treatment of from 125° to 145° F. for several hours, as recommended for bean and pea weevils in a recent Farmers' Bulletin (7), was not tried. Experiments indicated, however, that the horse-bean weevil is more difficult to kill than the ordinary bean weevil. Unless the heat can be easily controlled and not allowed to go much above 145°, other remedies will be much safer to use.

FUMIGATION.

Sulphur was first tried, using varying strengths up to 2 pounds to 100 cubic feet of space for a period of 3 hours, and proved unsuccessful.

The standard remedy for bean weevils, carbon disulphid, was next tried. The experiments were arranged to compare the effect of infested beans fumigated while the insects were in the immature stages and after all had reached the adult stage. Examination of beans during the experiment gave the following results:

TABLE XII.—*Development of Bruchus rufimanus Aug. 15 and 17, 1918, at Alhambra, Calif.*

	Per cent.
One-half to three-fourths grown larvæ-----	37.6
Full grown larvæ-----	20.9
Total larvæ-----	58.5
Pupæ-----	20.
Adults-----	21.5

TABLE XIII.—*Effect of carbon disulphid on the broad-bean weevil.*

Pounds CS ₂ per 1,000 cubic feet.	Percentage of beans with all weevils dead.			
	Exposed 18 hours.		Exposed 24 hours.	
	Treated in August.	Treated in October.	Treated in August.	Treated in October.
Check, not treated.....	43	14	43	14
2.....	55	.....	52	.....
3.....	55	.....	52	.....
4.....	69	83	60	81
5.....	70	94	82	96
6.....	60	90	62	99
7.....	74	100	79	100
8.....	.....	99	.....	100
9, 10, 12, 15, 20.....	.....	100	.....	100

Conclusions from the carbon disulphid fumigation experiments:

1. Exposure in October when the insects were in the adult stage gave a 20 per cent better result than in August, when they were in the larval stage.

2. A 24-hour exposure gave only about 2 per cent better results than one of 18 hours.

3. A 48-hour exposure gave about a 5 per cent better result than one of 24 hours.

4. Seven pounds to 1,000 cubic feet for 24 hours was the least amount to give a 100 per cent killing.

5. Germination is not affected by the treatment, as beans treated with 15 and 20 pounds per 1,000 feet for 24 hours gave 95 and 97 per cent germination.

Contrary to expectations, it was found that fumigating while the insects were in the larval stage was less effective than in the adult stage. A glance at Table XII will show that when the first fumigation took place in August, almost 40 per cent of the larvæ were not full grown. These were still eating within the bean, and had not come up to the epidermis and formed the "window" through which the adult emerges. It is evident, therefore, that the gas can not penetrate into the interior of the beans to the partially grown larvæ as easily as it can reach the full-grown larvæ, pupæ, or adults directly under the skin.

It was further observed that in the beans fumigated in August a number of full-grown larvæ and pupæ had been killed.

Lengthening the time of exposure did not greatly increase the percentage killed. This conforms to the opinions of Dr. W. E. Hinds (6) of the Alabama Experiment Station, who says, "As a matter of fact, most, if not all, of the killing will have occurred during the first 6 hours of the exposure, and the building may be ventilated after that time, as a minimum, has elapsed, although it is better to wait 12 hours or longer." On the effect of carbon disulphid on the germination of the seeds, Dr. Hinds states: "It would appear from numerous tests that there is practically no danger of injuring germination in treating seeds that are well matured and dried out before treatment is given. *It would not be wise to treat moist seeds, or planting seed of any kind, during periods of very humid atmosphere*, as the seeds might take up enough moisture to make them liable to injury from the vapor."

HOLDING OVER SEED.

Life-history studies showed that the horse-bean weevil had but one generation a year, that it did not breed in the dry beans, and that the last few remaining live adults died by the 1st of July. By merely holding the beans over, therefore, until the second year, they will be uninfested as far as live weevils are concerned. The beans should be stored in sacks or containers tight enough to prevent any live weevils getting out during the first season.

By referring to Table X, it will be seen that the germination of old seed is only slightly less than that of new seed.

Mr. Ronald McKee, in his bulletin on horse beans (8) previously mentioned, states: "Horse-bean seed retains its vitality for a number of years. * * * Germination tests of seed 4 years old of a number of varieties grown at Chico, Calif., showed little or no deterioration."

It can not be emphasized too strongly that any control measures to prevent weevil infestation should be undertaken by the entire community and not by a few growers. If all growers in the horse-bean districts would plant either absolutely uninfested beans, seed which had been given a thorough treatment with carbon disulphid, or seed which had been held over until the second year, the resulting crop would be of a very much higher quality as regards freedom from weevil infestation.

LATE PLANTING.

It has been observed for some time by horse-bean growers and buyers that the crops from seed planted early in the season were likely to be infested more badly than those from seed planted later. In administering the Food and Drugs Act, inspectors of the Federal Bureau of Chemistry collected samples of horse beans from all parts of the State, and ascertained for each sample the time of planting and the percentage of infestation. From the data furnished by them, and from samples taken and tested by the writer, the following tables were compiled. In Table XIV the growers did not know the exact date of planting, but remembered only whether they were planted early or late.

TABLE XIV.—*Comparing the degree of weevil infestation in crops planted early and late. Data from all horse bean districts in California.*

Year.	Planted early. ¹		Planted "later."		Planted late.	
	Number of sacks.	Percentage of infestation.	Number of sacks.	Percentage of infestation.	Number of sacks.	Percentage of infestation.
1916.....	17,100	32.5	.....	.....	5,380	6.3
1917.....	1,500	34.3	1,990	18.77	1,960	6.5

¹ Early means previous to January 1; late, subsequent to March 1.

Whenever possible, the month of planting the seed was ascertained in connection with the degree of infestation, and these data are given in Table XV.

TABLE XV.—*Comparing the degree of weevil infestation in horse beans from all districts in California, planted in different months.*

Year.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
1916.....	46	47	15.2	14.4	5.2	9.6	1	0
1917.....		50	15.6	17.5	8.21	12		
1918.....		30.1	19.1	18.5	15.7	12.9	4.3	.8
Average.....		42.3	16.6	16.7	9.7	11.5	2.6	.4

To test this out further, plantings of horse beans were made at Pasadena, Alhambra, and Hayward, for the years 1917 and 1918, in which a certain number of beans were planted each month, and when harvested carefully examined to find out the percentage of infestation. The results are given in Tables XVI and XVII.

TABLE XVI.—*Showing the percentage of weevil infestation of beans planted during certain months at Pasadena and Alhambra.*

Year.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.
1917 ¹		17	11.5	12	7.5	5	2.6
1918.....	43.5	45	15.5	8	.75		

¹ Degree of infestation for 1917 crop found by counting larval entrance holes, which are about 50 per cent greater than number of adult weevils.

TABLE XVII.—*Showing the percentage of infestation of beans planted during certain months at Hayward, Calif.*

Year.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.
1917.....				24	18	9.6	9.3
1918.....	74.5	67.5	32	14	5		

These tables clearly show that the later in the season the seed is planted the lower the percentage of infestation will be. A possible explanation of this may be found by referring to the seasonal history of the insect, which shows that egg laying begins about the middle of March, is heaviest in April, and extends to the middle of May. Figure 5 shows also that at Hayward the first adults were observed in a broad-bean field on March 18 and that the number constantly increased each week to May 4, after which the number decreased as constantly until June 15, the last date any were observed. Since the eggs are laid only on the pods, it follows that any plants which produced pods prior to or during April will be subject to the greatest egg deposition, and pods produced subsequently to the latter part of April would be liable to little or no egg deposition.

Seed planted from October to February begins setting pods in March and April, while seed planted from the latter part of February to May will begin setting pods from the latter part of April to June.

It would seem, therefore, from consulting the tables giving the percentages of infestation for seed planted in different months, from the insect's life history, and from the rate of growth and pod setting by the plant, that whenever possible it will be advisable to delay the planting until from the latter part of February or the first of March to May. A glance at Tables XIV and XVII will show that plantings prior to February and March show much higher percentages of infestation than those planted subsequently.

This contention is further borne out in the experience of the Oceano-Morro district in San Luis Obispo County. It was the custom there to begin planting about November, continuing all winter and spring. For several years the horse beans had been seriously infested with the bean aphid (*Aphis rumicis* L.) which also did severe damage to the later planted crops of small white and pink beans. Assuming that the early planted horse beans acted as a winter host for the bean aphid, propagating it in great numbers before the more extensive plantings of other beans were made, the horticultural commissioner persuaded all horse-bean growers to delay planting in the 1917-18 season until March 1. This agreement was adhered to with a few minor exceptions, and the result is shown in Table III. The maximum and average percentages of infestation for the Oceano-Morro district for 1916 are 50 and 14.5 per cent and for 1917, 63 and 14.5 per cent. In both these years a good share of the crop was from seed planted early, that is, from November to March, but in 1918, when practically no seed was planted until after March 1, the maximum and average per cent of weevil infestations are 17.2 and 2.92, a reduction of over 75 per cent. The majority of the plantings were not infested at all, particularly those which had been planted in April and May.

The planting season begins soon after the first rains, or ordinarily in October and November, in some sections, while in others it is delayed until spring. The former are the drier inland sections where the crop must be matured before the warm dry weather of the early summer, and the latter are the low, cooler, coastal valleys where the summer heat is not high enough to affect the crop.

The earlier plantings, especially in the dryer sections, usually produce larger crops than late plantings. This is particularly true where the beans are raised without irrigation. The climate and soil conditions, therefore, as well as the availability of irrigation water, must be taken into consideration in arranging for a delayed planting program. Where late planting can not be practiced because of these conditions, it is especially important that all seed either be uninfested or treated to kill the weevil before planting; but where conditions are favorable, planting should be delayed as late as is commensurate with getting a good crop.

RECOMMENDATIONS.

Only uninfested or treated horse beans should be used for seed. All horse beans used for seed which are infested with the broad-bean weevil either should be treated with carbon disulphid or held over in tight receptacles until the second year, when the weevils will all be dead.

Carbon disulphid should be used at from 7 to 10 pounds per 1,000 cubic feet, for at least 24 hours, in a box, barrel, or room as air-tight as it is possible to get. The smaller amount is effective in perfectly tight receptacles, but the larger amount should be used if the fumigating box or room is not tight. The liquid should be placed in a shallow pan at the top of the box or poured over the seed.

Infested seed which has not been treated and is held in warehouses or barns near broad-bean fields, except that held over for seed until the second year in tight receptacles, should be disposed of or fed before the planting season.

Badly infested seed should be ground up in feed mills immediately after harvesting.

Planting should be delayed until as late as possible, preferably after March 1. In the dryer and hotter localities where this is not possible, it is especially important to plant only seed which is uninfested or has been treated to kill the weevil.

All growers of horse beans should cooperate in carrying out these measures.

SUMMARY.

Broad-bean growing has been handicapped seriously by the presence of the broad-bean weevil (*Bruchus rufimanus*).

Although the first record of this insect's establishment in America was in 1909, it probably has been here since about 1888.

It is found in the entire broad-bean section of California.

The weevil not only lowers the value of the beans but has greatly reduced the acreage planted to that crop.

The insect has but one generation a year and does not breed in dry beans.

The egg stage is from 9 to 18 days; the larval stage, 10 to 15 weeks; the pupal stage, 7 to 16 days; and the adult stage, 1 to 8 months.

Eggs are laid on the green bean pods in the field from the middle of March to the middle of May; the larvæ reach maturity from August to October, while adults can be found from August to the following June.

Germination of infested beans is from 20 to 40 per cent less than that of uninfested beans.

Germination of seed a year or more old is only slightly less than that of new seed.

There are no natural enemies of the broad-bean weevil of any consequence in America.

It requires 170° to 180° F. for over half an hour to kill all of the weevils in broad beans.

Sulphur is unsatisfactory as a fumigant.

Carbon disulphid at the rate of 7 pounds per 1,000 cubic feet in a tight box for 24 hours kills all the weevils.

In seed held over until the second year all the weevils are dead.

Beans from crops planted late, after March 1. are much less infested than those planted earlier, from November to March.

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L. O. HOWARD, Chief

Washington, D. C.

PROFESSIONAL PAPER

February 24, 1920

STUDIES ON THE LIFE HISTORY AND HABITS OF THE
JOINTWORM FLIES OF THE GENUS HARMOLITA (ISO-
SOMA), WITH RECOMMENDATIONS FOR CONTROL.¹

BY W. J. PHILLIPS,

Entomological Assistant, Cereal and Forage Insect Investigations.

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INTRODUCTION.

Owing to the chaotic condition existing until recently in the classification of the genus *Harmolita* (*Isosoma*), it has been practically impossible to obtain specific determinations, and this fact has largely prevented economic workers from undertaking detailed life-history studies of the various species. Some members of this genus are of great economic importance, the losses directly traceable to them

¹ The writer wishes to acknowledge his indebtedness to various members of the branch of Cereal and Forage Insect Investigations who furnished material from time to time for breeding work, but more particularly to Messrs. W. T. Emery, Philip Luginbill, and T. H. Parks, and to Dr. Henry Fox, who have been associated with him and have rendered valuable assistance in breeding, and to Mr. A. B. Gahan for kindly criticisms of the manuscripts.

running into the millions of dollars every year. Despite this fact very little has been known concerning the identity and habits of the species which cause these losses. For example, it was not known definitely whether *Harmolita tritici* Fitch, the most important member of the genus, had a dozen host plants or whether it was confined to wheat alone. The object of this paper, therefore, is to place on record in as brief a manner as possible the main facts, in so far as they have been developed, in the life histories of the species that have been studied thus far, and to propose a basis for control.

The species infesting the grain crops will be considered first, then those affecting the cultivated grasses, and lastly the species living in wild grasses. Nearly every species is of either direct or indirect economic importance. Those affecting the grain crops and the cultivated grasses are obviously of direct economic importance because of the very considerable losses entailed by their depredations or their potential capacity for injury. The importance of the different species varies greatly since the damage inflicted by some is far greater than that caused by others. The economic aspect of those species affecting wild grasses is less obvious. They do not cause a loss to the farmer, but on the contrary probably are an advantage to him, since they serve as intermediate hosts for the many parasitic insects which play such an important rôle in the natural control of the species infesting cultivated crops. Without these intermediate hosts it is doubtful whether some of the parasites would be able to maintain themselves under the abnormal conditions created by cultivation. The more important species of parasites are common to the majority of species of *Harmolita*, however, and consequently are able to survive those periods during which there is a lack of hosts breeding in cultivated crops, by turning their attention to related species breeding in wild grasses.

It is difficult to estimate the value of jointworm parasites in terms of dollars and cents to the wheat-growing regions east of the Mississippi River. The writer is convinced, however, that farmers would have been obliged to resort to artificial measures of control for the wheat jointworm years ago had it not been for the efficiency of these parasites. The parasites of the jointworms will be treated in a paper to be published subsequently.

SPECIES INFESTING THE GRAIN CROPS.

THE WHEAT JOINTWORM.¹

Harmolita tritici probably is the most important species in the whole genus, since it causes very serious losses in nearly all the wheat-producing States east of the Mississippi River and in a large part of

¹ *Harmolita tritici* Fitch.

Missouri. It has been known as a serious wheat pest since 1848 and it is strange that it has not extended its range into the great wheat-producing States of Texas, Oklahoma, Kansas, Nebraska, the Dakotas, and farther west. At present no satisfactory explanation of this fact can be offered, although the species undoubtedly will invade that part of the country sooner or later. *Harmolita tritici* has been confused in literature with *H. hordei*, *H. secalis*, *H. captiva*, *H. vaginicola*, *H. elymicola*, and doubtless with others. It was first described by Asa Fitch (3)¹ in 1859 as *Eurytoma tritici* and was subsequently described under several names by various authors. Entomologists disagreed for years regarding this species before the phytophagous habits were definitely established.

MANNER OF INJURY.

A plant infested by the wheat jointworm may not show any external signs of infestation whatever, or the stems may be distorted and have wartlike elevations on them (Pl. II, C). In any case the stem at the point infested is hard and woody and where there is no distortion the point of infestation may be readily detected by pinching the stem between the thumb and forefinger. These infested places usually occur above the second or third joint from the root but may occur above any joint. In badly infested fields several joints may be affected and a large number of plants may fall (Pl. I, B), thus greatly reducing the yield. It is not necessary, however, that the plants fall or lodge to reduce the yield greatly. The writer has taken heads from healthy and from infested stems, carefully measured them against one another, and has found that the grain of the infested plants from the same number of heads of exactly the same length as the uninfested were very much lighter and of much smaller volume (Pl. I, A).

When plants lodge or fall to a considerable extent the yield is far more reduced than when the plants remain standing. In the first place, the plants that fall, in nearly every case, will escape the binder. Should the binder reach them they will be bound so near the butt of the bundle that most of them will fall out with subsequent handling. Could they be bound securely the yield would scarcely be 50 per cent as large as that from heads of equal length taken from normal plants. The grains, moreover, are small and somewhat shriveled. The inferior grain seems to be due to improper nourishment during the growing period. The young larvæ develop in the walls of the stem and disarrange the fibro-vascular bundles, thus greatly weakening the stem at this point. A storm, light rain, or heavy wind will cause the plant to bend over at the point of in-

¹ Numbers in parentheses refer to "Literature cited," p. 26.

festation, as the plants are thus made much more top-heavy. As the growing larvæ consume proportionately large amounts of sap, the developing wheat kernels are constantly robbed of their nourishment and suffer accordingly.

A field of wheat badly straw-fallen usually is attributed to the depredations of the Hessian fly by the average farmer, and very often the fly is wrongly credited year after year, in the States east of the Mississippi River, with serious and widespread injury that is chargeable to the jointworm.

HOST PLANTS.

During repeated trials covering a number of years this species was never induced to breed in any plant but wheat. It never has even

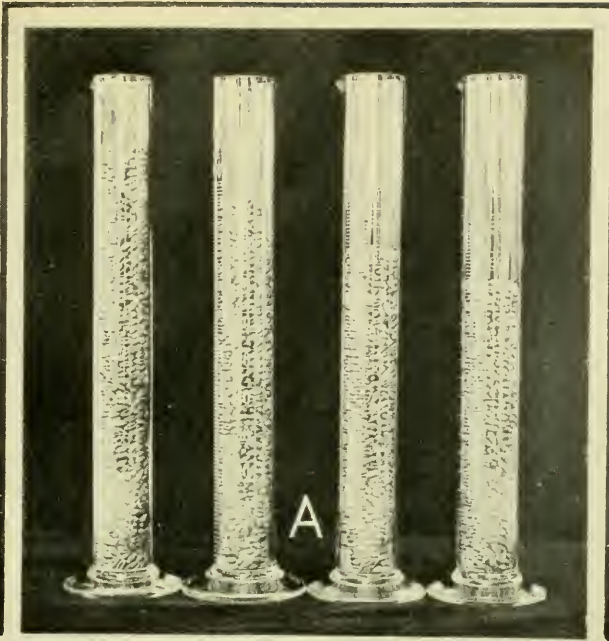


FIG. 1.—The wheat jointworm (*Harmolita tritici*): Adult female. Greatly enlarged. (The head is tilted back somewhat so as to show the groove in front.) (Author's illustration.)

been observed to attempt oviposition in any other plant. The stems of barley and rye particularly do not differ greatly from wheat, but they seem to be distasteful to *tritici*.

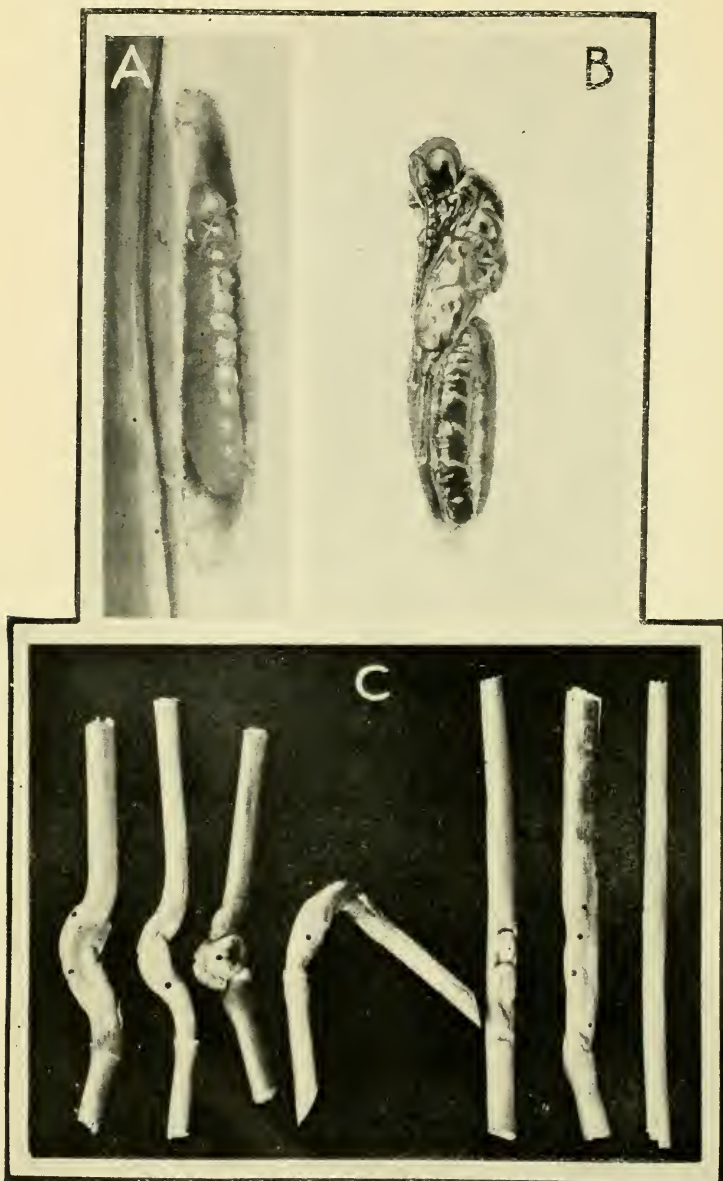
LIFE HISTORY.

There is only one generation a year. The adults (fig. 1) emerge in May and deposit their eggs in the stems of growing wheat just about the time the heads begin to appear. The life of adults lasts from a few days to a week or more, depending upon the temperature. The eggs (fig. 2, *a*, *b*) hatch in about 10 days. The larvæ mature in



JOINTWORM FLIES OF THE GENUS *HARMOLITA*.

A, Comparative yields from healthy wheat plants and those infested with the jointworm (*Harmolita tritici*); reading from left to right, the yield from 85 uninfested stems, 85 stems with one node infested, 85 stems with two nodes infested, and 85 infested fallen straws. The heads were all measured against each other, so that, for example, any head from the lot of uninfested plants had a corresponding head of equal length in all the infested lots; B, Field badly infested with the jointworm. Note the large percentage of fallen straws.



JOINTWORM FLIES OF THE GENUS HARMOLITA.

H. tritici: A, Cell with the top lifted off exposing the larva (greatly enlarged); B, pupa (greatly enlarged); C, characteristic galls (about natural size).

about three weeks or a month from date of oviposition. They molt at least three times and possibly four. The larvæ (Pl. II, A) are yellow, footless grubs, three-sixteenths of an inch long at maturity. They remain in the larval stage until late fall or early winter, when the majority usually change to pupæ (Pl. II, B), the remainder pupating very early in the spring.

Males normally occur, although in confinement this species will breed parthenogenetically, in which case the progeny are all males.

THE WHEAT STRAW-WORM.¹

Harmolita grandis ranks next to the wheat jointworm in importance as an enemy of wheat. Were it not for the ease with which it can be controlled it probably would be more destructive, and might even command greater prominence than the Hessian fly, due to the fact that there are two generations a year. At any rate, it is at present the most important of the jointworm group west of the Mississippi River, where it often causes widespread injury. *H. grandis* is probably the most widely distributed species in the United States, occurring usually in greater or less numbers wherever wheat is grown. Though occurring in



FIG. 2.—Eggs of species of *Harmolita*: a, *H. tritici*, after oviposition; b, *H. tritici*, before oviposition; c, *H. elymivora*, before oviposition; d, *H. hordei*, after oviposition; e, *H. hordei*, before oviposition; f, *H. grandis*, form *minuta*; g, *H. agropyrophila*. All greatly enlarged. (Original.)

¹ *Harmolita grandis* Riley.

practically every wheat-growing section east of the Mississippi River, it rarely has caused any serious losses in recent years, although it exacts a small toll annually. This possibly may be explained by the fact that wheat fields in the Eastern States are located usually at a distance from the old stubble fields of the previous year, and since the spring generation is wingless, only a small percentage of the individuals is able to make the journey safely from one wheat field to another, and it thus becomes difficult for the species to maintain itself.

H. grandis is a comparatively old offender, but probably has escaped being confused with other species, as it has some rather striking characters, though the fact that it is dimorphic greatly perplexed all entomologists for a number of years. Each form was considered and described as a separate and distinct species. Riley



FIG. 3.—Wheat straw-worm : Wingless adult female of spring form (*Harmolita grandis*, form *minuta*). Greatly enlarged. (Webster and Reeves.)

(11) described the spring form as *Isosoma tritici* in 1882, since he considered Fitch's *tritici* as a synonym of *hordei* Harris. In 1884 the late F. M. Webster established the dimorphic habits of *grandis*, rearing both forms, and Riley (12) described the summer form as *Isosoma grande*. In 1896 Howard (8, p. 10) definitely established Fitch's *tritici* as a valid species and gave the name *minutum* to the vernal generation of Riley's species previously referred to in literature as *tritici*. *H. grandis* is probably the most interesting species of the whole group. There is one other species that has two generations during the year, but no others, so far as is known, are dimorphic.

HOST PLANTS.

The writer has never succeeded in rearing *H. grandis* from any plant but wheat. He has observed it oviposit in other plants but no larvæ were ever found in them. Further experiments along this line may disclose other hosts. As it is found in sections where very little wheat is grown consecutively, it seems as though there must be at least one other host.

LIFE HISTORY AND MANNER OF INJURY.

The spring form (fig. 3) (*H. grandis*, form *minuta*) attacks the wheat plants when they are small (fig. 4), the eggs (fig. 2, *f*) being deposited in the base of the young plant. The developing larva totally destroys the tiller affected, and if the plant has not tillered

it kills the entire plant. The larva develops within and right at the base of the plant, usually making the plant somewhat bulblike at this point (fig. 5). This generation emerges during March and April in the Eastern and Central States, while in Washington and probably in other Pacific States it emerges in April. This spring generation usually is wingless, though occasionally specimens may have wings. These winged individuals usually are imperfect in that they often have only two or three wings. Sometimes only the front pair are present, and

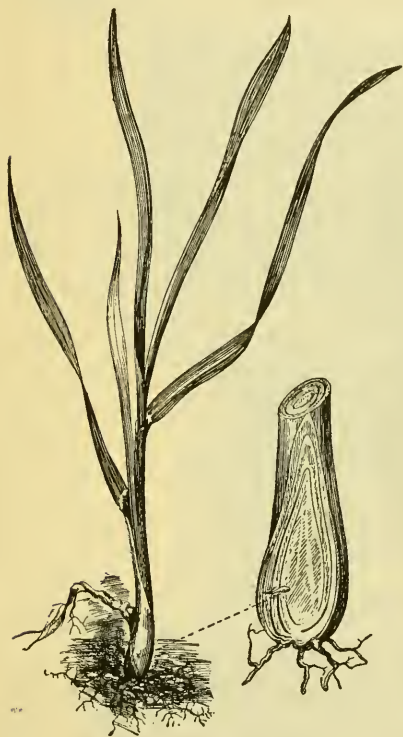


FIG. 4.—Wheat straw-worm; Stage of development of wheat plant at time of oviposition of spring form (*Harmolita grandis*, form *minuta*). Enlarged illustration at right shows the point where egg is deposited. (Webster and Reeves.)



FIG. 5.—Wheat straw-worm; Pupa of summer form (*Harmolita grandis*, form *grandis*) as it normally occurs in the field. The tiller thus attacked is always killed. (Webster and Reeves.)

again only the hind wings. Males occasionally occur in this generation, though rarely.

The summer form (fig. 6) (*H. grandis*, form *grandis*) emerges in May and deposits eggs (fig. 7, *d, e*) in the growing wheat plants slightly above the joints, often placing the eggs directly in the cavity of the stem, where they hatch in about 5 days. Sometimes

they are placed in the walls. Several eggs are placed occasionally in the same joint but the writer never has found more than one full-grown larva at a joint, the others apparently being killed by the surviving larva. The larva rasps the inner walls of the stem, sucks the juices, and subsequently forms a neat little cell within the joint (Pl. IV, B). In all the winter wheat areas the effect upon the plant is to cut down the yield of grain, while in places where both spring and winter wheat are sown, often in adjoining fields, the summer form turns its attention to the spring wheat in preference to the older and tougher plants of the winter wheat. Spring wheat is affected very much in the same manner as winter wheat is

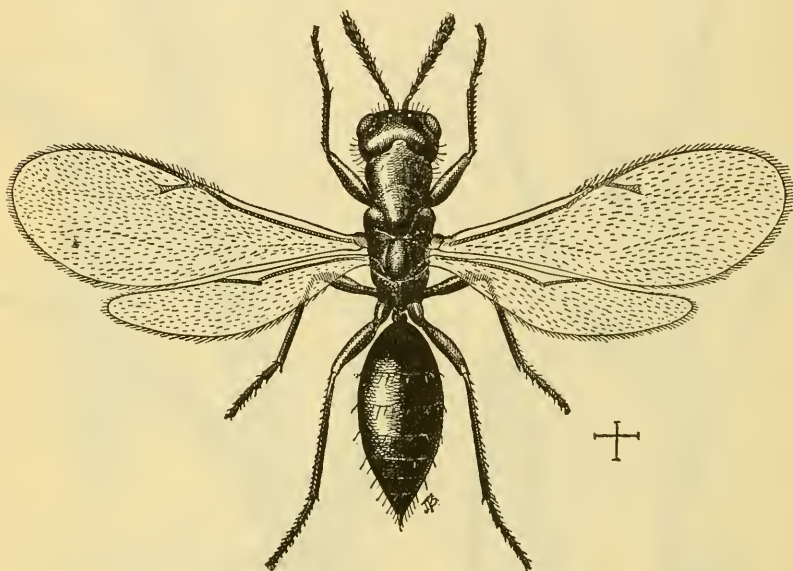


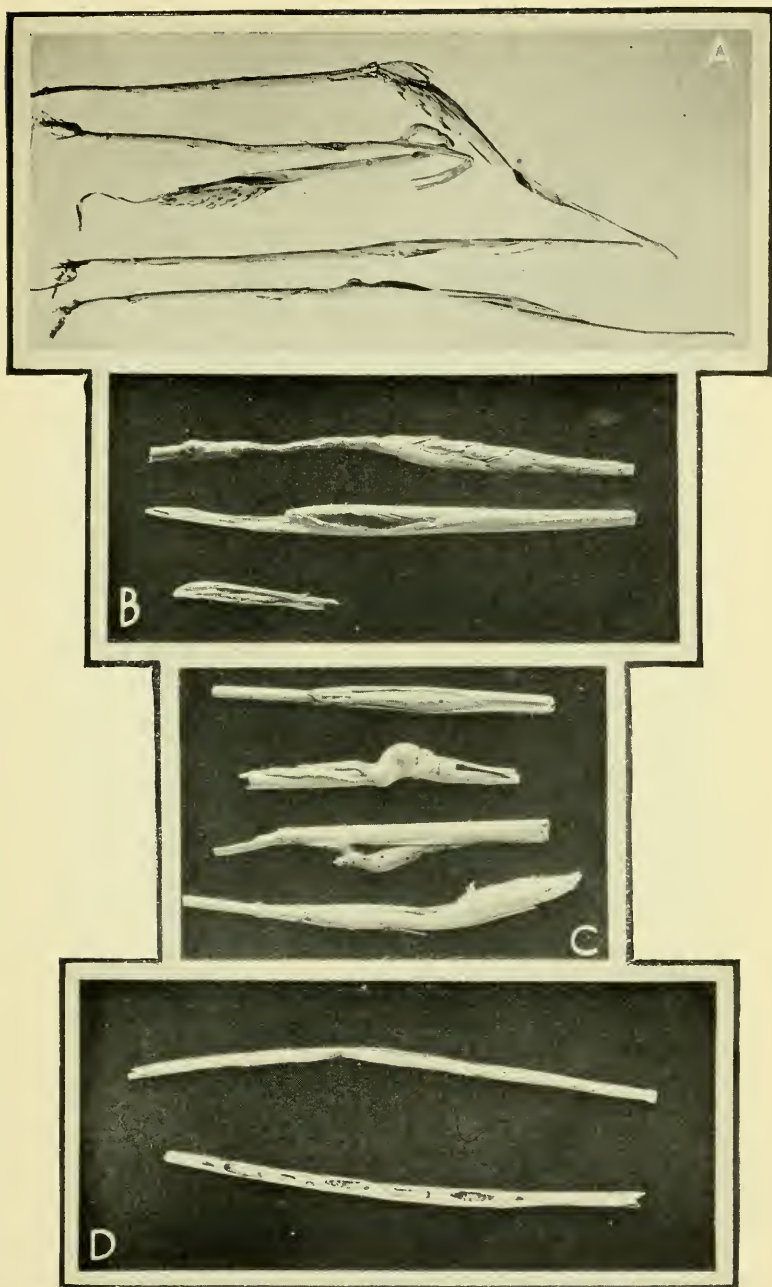
FIG. 6.—Wheat straw-worm: Adult female of summer form (*Harmolita grandis*, form *grandis*.) Greatly enlarged. (Webster and Reeves.)

injured by the first generation (form *minuta*). The summer generation remains in the old wheat stubble, pupating in the fall. The spring generation, as previously stated, emerges in March and April. The writer has never seen males of the summer generation.

THE WHEAT SHEATH-GALL JOINTWORM.¹

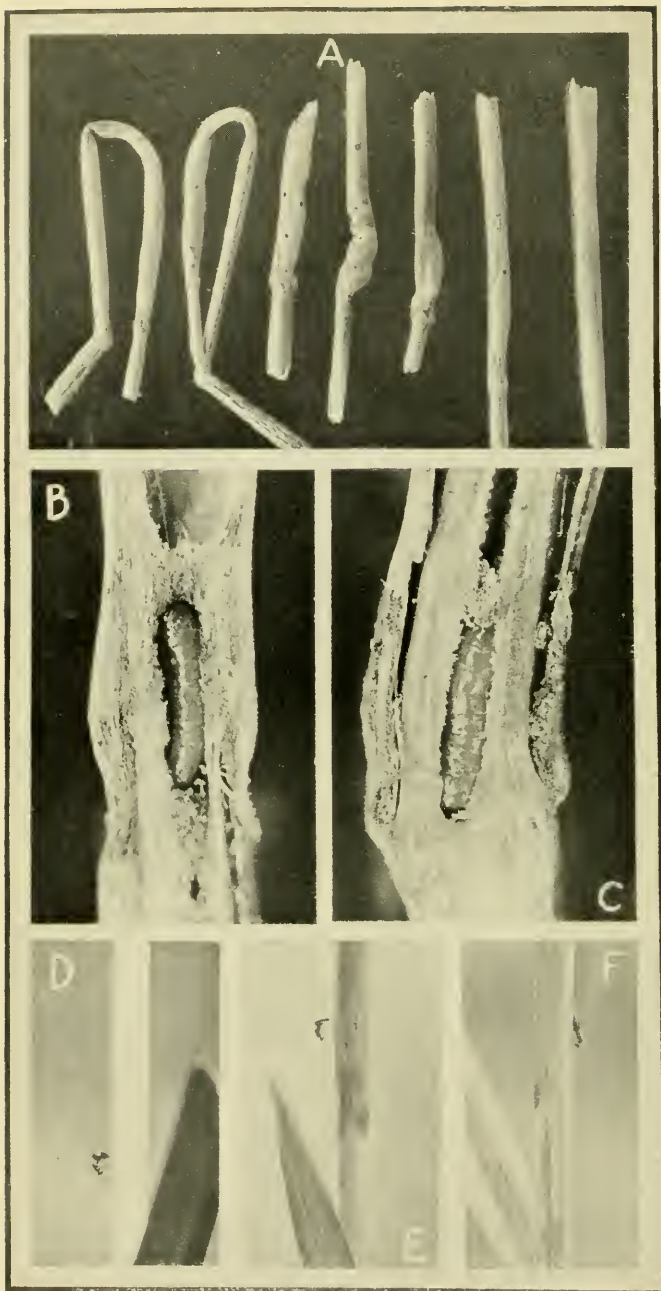
Harmolita vaginicola was not described until 1916 (2), though the typical form of its injury to wheat was recorded in literature many years ago. There are specimens in the National Museum collection that bear the manuscript name *Pteromalus hordei* Harris, which were collected in Virginia in the early fifties, and some that

¹ *H. vaginicola* Doane.



JOINTWORM FLIES OF THE GENUS HARMOLITA.

A, Characteristic manner in which *H. vaginicola* dwarfs wheat plants. These plants rarely form grain. About one-third natural size; B, Head from a plant dwarfed by *H. vaginicola* with the surrounding leaf sheath removed, showing the galls in the sheath and not in the stem. Slightly reduced; C, Characteristic galls of *H. vaginicola*. Note the rootlike growth at the base of galls. Slightly reduced; D, Galls of *H. captiva* in bluegrass (*Poa pratensis*). There is little external evidence of the galls. Note that the galls are placed end to end. Slightly reduced.



JOINTWORM FLIES OF THE GENUS HARMOLITA.

A, Characteristic galls of *H. hordei*, some clearly showing that the plants were straw-fallen. About actual size; B, Larva of *H. grandis* form *minuta* in a cell in the center of a wheat stem. Greatly enlarged; C, Larva of *H. albomaculata* in a timothy stem (*Phleum pratense*). Greatly enlarged; D, *H. hordei* touching the ovipositor to barley stem, the first process in oviposition; E, forcing the ovipositor into the stem, the second step; F, the ovipositor completely down, the third and last step, and the abdomen resting lightly against the stem. About natural size.

were collected in Ontario, Canada. There are specimens in the Harris collection of the Boston Society of Natural History bearing the label *Isosoma tritici* that were collected in Virginia in 1852. There are also specimens of *tritici* in the same lot. As late as 1892 F. M. Webster (13) stated that—

He had not reared the depredator, and though in many respects the attack seemed to agree with that of *Isosoma hordei*, as described by Harris and Fitch, yet in many other features it appeared different. In all cases—and he had examined hundreds of wheat straws from northern Ohio—the attack was always above the upper joint. In two cases the upper joint and the one below had been attacked. From many thorough examinations he had found that the stem itself had not been eaten into, the cells being formed in the sheath, but owing to the pressure of the galls on the tender stem the latter had become distorted and the upper portion with the head, where one was produced, was greatly aborted.

This so accurately describes the injury that no doubt is left as to the identity of the insect in question or as to the fact that the species was very widespread and may have been a more serious pest in the early days in Michigan and northern Ohio than *H. tritici*. This is one of the reasons why entomologists had such controversies over *tritici* in the early days. There is not the slightest doubt in the



FIG. 7.—Eggs of species of *Harmolita*: a, *H. hesperus*; b, *H. websteri*; c, *H. albomaculata*; d, *H. grandis*, form *grandis*, after oviposition; e, *H. grandis*, form *grandis*, just before hatching. All greatly enlarged. (Original.)

writer's mind that if the types of all of the early described species now referred to synonymy were in existence to-day and were recognizable, *vaginicola* would be found among them. *H. vaginicola* was very probably confused with *hordei* and *secalis* as well as *tritici*.

The writer's earliest personal records of *vaginicola* are from collections from eastern Ohio in 1912. Since then he has recorded it from Michigan, New York, and Pennsylvania and has been rearing it in confinement since 1914. Mr. Desla Bennion sent the writer specimens from Salt Lake as early as 1914 and Mr. L. P. Rockwood recently submitted a single gall from Oregon, from which this species has emerged.

MANNER OF INJURY.

H. vaginicola affects the plants in a very peculiar way, and only one other species, namely, *atlantica*, a gall-former in *Agropyron* sp., is known to the writer to affect a plant in a similar manner. The eggs (fig. 8, *a*) are deposited in the tender leaf sheath surrounding the embryonic head. It does not seem possible that the insect can always locate this delicate structure so easily. The result is that as the plant grows, the

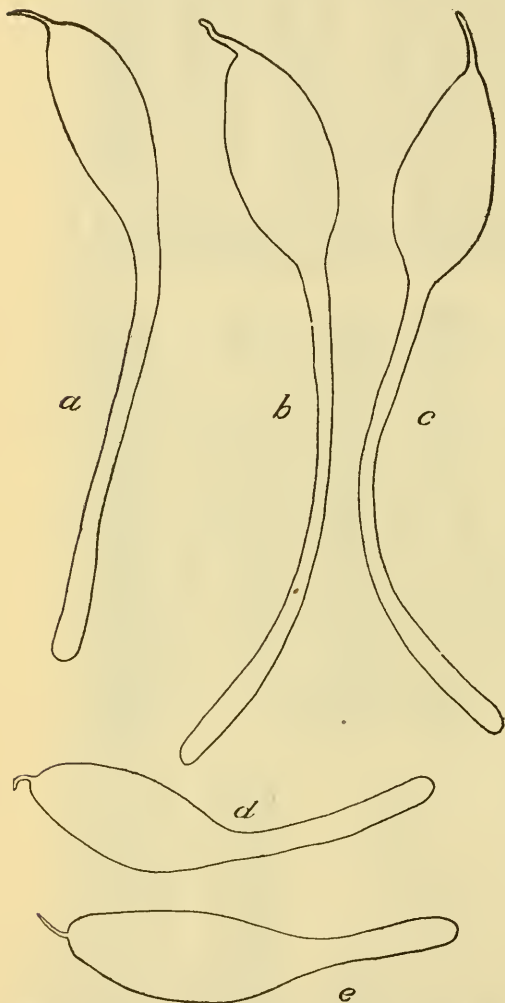


FIG. 8.—Eggs of species of *Harmolita*: *a*, *H. vaginicola*; *b*, *H. secalis*; *c*, *H. clymicola*; *d*, *H. maculata*; *e*, *H. poae*. All greatly enlarged. (Original.)

leaf sheath surrounding the developing head becomes fleshy and thick instead of remaining thin and leaflike. Later this thickened, fleshy leaf becomes hard and woody and compresses the stem to such an extent that little or no sap can reach the developing head. Consequently the head usually protrudes only an inch or

two beyond the leaf sheath. Sometimes it does not even burst through the sheath and rarely if ever do any of these heads contain grain (Pl. III, A, B, C). The larval cells are contained in the hardened leaf sheath.

Why this species has not become the dominant pest of wheat, at least among the jointworm group, is inexplicable. It is prolific and the plants attacked seldom if ever produce any grain. The species has been in this country for at least 55 or 60 years. The only explanation that occurs to the writer, of the reason it has not proved more injurious, is that it seems unable to breed in strong, well-grown plants. In other words, by the time the adult emerges in the spring, the majority of the wheat plants are well grown and about to begin heading. This is true, at least, for the States east of the Mississippi River. It seems necessary that plants be small and the heads in an immature tender stage for this species to be able to breed in them. The species absolutely refuses to oviposit in large plants that are about ready to head. Should this pest once become established in the spring wheat belt, the writer is of the opinion that it will be a very serious pest, owing to the fact that the adults would undoubtedly emerge when the wheat plants were young and tender and most attractive to them, as is known to be the case with *grandis* where the spring and winter wheat regions overlap.

HOST PLANTS.

H. vaginicola steadily has refused to breed in any plant other than wheat. The writer never has observed it even to attempt oviposition in any other plant, and, as previously stated, the plants must be young and tender or it will refuse them.

LIFE HISTORY.

There is only one generation a year. The larvæ remain in the wheat stubble until the following spring, then pupate and emerge as adults in May. The abdomen of the female contains 60 to 70 eggs. They are normally thelytokous. During the 4 years the writer has been rearing this species in confinement no males have been observed, though thousands of specimens have been reared.

THE BARLEY JOINTWORM.¹

The records show *Harmolita hordei* to be the oldest species recorded in literature in the United States, and, like *tritici*, it has caused a storm of argument. In fact, for many years it was sup-

¹ *Harmolita hordei* Harris.

posed to be the only species present, and even *tritici* was considered a varietal form of it. Harris (7) described this species in 1830. Along in the twenties it caused such serious injury to barley in Massachusetts that the growing of this crop was abandoned in some sections. For years it was a scourge to barley-growing sections in the East. The Eastern States have largely ceased growing barley for a number of years now, and consequently have suffered very little injury. The barley-growing section has moved west, Wisconsin, Minnesota, and the Dakotas now being the most important barley States. Fortunately *hordei* does not seem to have been introduced artificially into those sections, which is the only plausible way it could be transferred from the main barley section in the East. Barley, unlike wheat, is not grown generally in the intervening States, so that there is no chance for *hordei* to spread gradually westward as *tritici* seems to have done.

During the late summers of 1913 and 1914 the writer visited portions of New York State that were formerly great barley-growing centers. Only a very few infested barley stubbles were found after extended search in 1913, and none were found in 1914. Very little barley is grown there now. The fields, as a rule, are widely separated and the stubble usually is plowed under before *hordei* has had an opportunity to emerge, consequently it has been almost exterminated. This is one of the very rare instances of a once serious pest becoming practically extinct. Its scarcity is such that the writer had never seen a specimen of *hordei* until the spring of 1914, except the few fragmentary specimens in museums.

H. hordei has been confused with *tritici* and *secalis* undoubtedly, and probably with *vaginicola* and others. As the coloration of the legs of *hordei* varies to a considerable degree it is not surprising that confusion arose years ago, since that was one of the main characters used in identifying the species.

MANNER OF INJURY.

Barley plants are affected by *hordei* (Pl. IV, A) in exactly the same manner as wheat plants are by *tritici*. In fact, but for the slightly different appearance of barley straw from wheat straw, the galls could not be separated once they became mixed. When barley plants are badly infested galls may be found above every joint.

HOST PLANTS.

The writer has now been breeding *hordei* in confinement for 4 years and has never succeeded in inducing it to breed in any plant other than barley.

LIFE HISTORY.

This is one of the easiest species to handle in breeding cages. In fact, it breeds more freely than any other species, *tritici* not excepted.

There is only one generation a year, the larvæ remaining in the old barley stubble until the following spring, when they pupate and then emerge as adults during May, at least in the vicinity of Charlottesville, Va. Plate IV, D, E, and F, shows three positions of a female during oviposition. Figure 2, *d*, *e*, shows the egg before and after oviposition.

H. hordei is normally thelytokous. In a period of 4 years' breeding, during which several thousand specimens have been reared, not more than three or four males have appeared.

Under actual test one female *hordei* deposited 71 eggs in 3 days and then died. Upon dissection 3 eggs were found in her abdomen. From this it would seem that under favorable conditions for egg laying the lives of adult females of the species are very short. If the weather is stormy and cool, however, they will live two or three times as long.

THE RYE JOINTWORM.¹

The rye jointworm was described in 1861 (4), so it will be seen that it is one of our earliest known species. For years, however, it was considered an invalid species and was thought to be *hordei* masking under a new name. There appears to be no record of the rye jointworm ever doing as serious injury as *tritici*, *hordei*, or *grandis*.

Harmolita secalis, like *hordei*, is almost extinct to-day and apparently for the same reasons. In fact, it never has had the opportunity to become a serious pest on account of the fact that rye probably has never been grown as generally in adjacent fields and through consecutive years as have barley and wheat. The rye jointworm has had to depend largely upon volunteer rye and to make long journeys to the nearest rye fields in order to maintain itself.

The rye jointworm, in common with several other members of the genus, is thelytokous, males very rarely occurring and apparently being unnecessary to the vital economy of the species. But for the fact that practically every specimen that emerges is a female and capable of perpetuating its kind, *secalis* would undoubtedly have become extinct long ago.

Fitch described *secalis* from Pennsylvania in 1861. F. M. Webster collected the species in Ohio in 1904 and C. N. Ainslie collected it in Michigan in 1906. The writer has collected it in Ohio, Indiana, and Pennsylvania.

¹ *Harmolita secalis* Fitch.

MANNER OF INJURY.

Rye plants are affected very much in the same way as are wheat by the wheat jointworm and barley by the barley jointworm. The individual cells or galls in rye (Pl. V, A) usually are more clearly defined or outlined than are those of *H. hordei*. Presumably a serious infestation would cause rye to lodge or fall as badly as barley or wheat, since rye is taller and therefore more top-heavy. The writer has never found a serious infestation of *secalis*, apparently because, as previously mentioned, no locality has been found where rye is grown consecutively on contiguous areas, in consequence of which *secalis* is obliged to resort to volunteer plants that spring up in waste places to maintain its existence at all.

HOST PLANTS.

After 3 years of repeated trials this species has refused to breed on any plant other than rye. Like *vaginicola* it prefers young tender plants for oviposition, absolutely refusing to oviposit in large plants or those that have headed.

LIFE HISTORY.

The writer has had this species under observation since 1912, when the first attempts were made to rear it in confinement. It was reared continuously from that time up until 1916. During 4 consecutive years of breeding only 2 or 3 males appeared among hundreds of specimens all of which were the progeny of 6 female and 4 male individuals with which the series was started in 1912.

The larvæ remain in the old stubble throughout the summer, fall, and winter, pupate in the spring, and emerge as adults about the middle of May. The egg is shown in figure 8 at *b*.

The species *secalis* has been confused principally with *hordei* and undoubtedly also with *tritici* and *websteri*.

THE RYE STRAW-WORM.¹

The rye straw-worm is another early recorded species, having been first described in 1862 by Fitch (5) under the name *Eurytoma hordei*. There is no record that it ever caused serious injury to rye, and under the conditions that prevail to-day of scattered cultivation of this crop there seems little prospect that it will become a serious pest. In fact, like several other species, it seems to be having a very hard fight to maintain its existence. F. M. Webster collected *websteri* in Illinois in 1884, and D. W. Coquillett took it in California

¹ *Harmolita websteri* Howard.

in 1885. Webster observed this species in rye stalks in Indiana, Ohio, and Virginia in 1904. Since that time the writer has collected it in Ohio, Indiana, and Pennsylvania.

MANNER OF INJURY.

The larva works in the center of the stem just at the joint, in the same way as does the summer form of the straw-worm. The writer has never seen a heavy infestation by this species.

HOST PLANTS.

The writer has bred this species for 8 years in confinement and made various attempts to induce it to breed on other hosts, but without success; it confines itself exclusively to rye.

LIFE HISTORY.

Starting originally with 2 females and 1 male, the writer has reared this species in confinement since 1911. All successive generations are the progeny of these individuals, and among several hundred specimens reared only 1 or 2 males have appeared.

There is only one generation a year and the larvæ remain in the old stubble until spring when they change to pupæ, the adults emerging about the middle of May. The egg is shown in figure 7 at *b*.

SPECIES INFESTING THE CULTIVATED GRASSES.

THE TIMOTHY STRAW-WORM.¹

The timothy straw-worm has been known since 1894, when it was described by Ashmead (1). Nothing seems to have been learned about its life history until recent years. It is very widely distributed and undoubtedly may be found wherever timothy has escaped from cultivation and grows wild. It is not dependent, therefore, upon artificial plantings of timothy.

MANNER OF INJURY.

H. albomaculata occupies the center of the stem, rasping the inner walls and feeding upon the juices of the plant (Pl. IV, C). Usually it is found just at or slightly above the second joint from the root though it may occur at any joint or at every joint. The injury is apparently not sufficient to decrease the hay crop materially, although a heavy infestation certainly would have a considerable effect in lessening the seed crop.

¹ *Harmolita albomaculata* Ashmead.

HOST PLANTS.

This species has been bred in confinement since 1909 and numerous attempts have been made to rear it on hosts other than timothy, with negative results.

LIFE HISTORY.

Larvæ remain in old stubble and in volunteer growth in waste places throughout the summer and winter, pupating in spring. The adults emerge in May. Males normally occur. The egg is shown in figure 7 at *c*.

THE ORCHARD GRASS STRAW-WORM.¹

The orchard grass straw-worm was recently described by the writer and Mr. W. T. Emery (10, p. 446). It was found first in 1904 by F. M. Webster, according to Bureau records. Since that time it has been collected by various members of the branch of Cereal and Forage Insect Investigations. The writer has been rearing it in confinement since 1914. It has been reared from orchard grass collected in Massachusetts, New York, Pennsylvania, Ohio, Michigan, Maryland, Virginia, Tennessee, and Utah.

MANNER OF INJURY.

H. dactylicola affects the plant in the same manner as does *albomaculata*. The writer has never found orchard grass as seriously affected as timothy, one reason probably being that it is not grown as generally. Orchard grass probably will not be as seriously injured by *dactylicola* as timothy is by *albomaculata* since the former plant is larger and more woody than timothy.

HOST PLANTS.

This species has not been reared from any host other than orchard grass.

LIFE HISTORY.

Larvæ remain in the old stubble and in old volunteer plants throughout the summer and winter, pupate in the spring, and emerge as adults in May. Males normally occur.

THE BLUE-GRASS JOINTWORM.²

Howard (8, p. 13) first described the blue-grass jointworm in 1896 from specimens captured by F. M. Webster in a rye field in 1885 at Normal, Ill. Webster later swept it from timothy and blue-grass at La Fayette, Ind. (14; 8, p. 13). Lintner (9) states that he reared a number of specimens of this jointworm from galls in wheat

¹ *Harmolita dactylicola* Phillips & Emery.

² *Harmolita captiva* Howard.

stems in New York in 1888. It is supposed that *captiva* was the species involved in the latter case, but doubt is cast upon this supposition by Lintner's statement that part of the specimens were typical *hordei* (*tritici*), and part were much larger, the latter being *captiva*. The species the writer knows as *captiva* is much smaller than *tritici*; besides, *captiva* has been reared from galls in blue-grass, and should it breed in wheat also it will be the second species known to infest plants belonging to separate and distinct genera. This is not at all impossible but at present it seems improbable. As the New York case is the only one recorded where the species has been reared from wheat it seems reasonable to suppose that another species than *captiva* was involved.

The writer reared specimens of *captiva* from galls in blue-grass collected near Richmond, Ind., in 1905. It has not been reared since. Nothing is known of its life history except that it undoubtedly has only one generation a year and that both males and females were reared. The galls (Pl. III, D) occur near the base of the seed stalk where the stem is thick. As the seed stalks of blue-grass are slender and rather frail the stem at the point where the galls occur does not seem to be very woody. The cells are arranged in a row end to end, there being insufficient room, apparently, for the larvæ to have cells side by side in the stalk as in some other species.

THE BLUE-GRASS STRAW-WORM.¹

The blue-grass straw-worm was described only recently by the writer and W. T. Emery (10, p. 445) but undoubtedly has been breeding in blue-grass (*Poa pratensis*) for years. Very probably it has been confused with *H. captiva* and perhaps with other species. The first records of *poæ* are by F. M. Webster and the writer in 1905. It is a widely distributed species and doubtless can be found wherever blue-grass grows normally.

MANNER OF INJURY.

The writer has never had the opportunity to visit sections that grow blue-grass seed to learn to what extent infestation exists. The only infestation found has been where the grass grows wild in protected places, such as along fences. Pastures usually are kept cropped close by stock and there is little chance for *poæ* to breed. It works in the center of the stem and undoubtedly would injure the seed crop greatly, as the seed stalks of blue-grass are slender, soft, and rather fragile, not at all hard and woody like the majority of the grasses affected by other species. The cavity in the stem is scarcely

¹ *Harmolita poæ* Phillips and Emery.

large enough for the larva, and as the walls of the stem are very thin it is easy to see that the larva would consume a large part of the nourishment required for the developing seed and cause serious loss in case of a heavy infestation.

HOST PLANTS.

H. poae has not been reared from any host other than blue-grass (*Poa pratensis*) although a number of attempts have been made to breed it in other hosts.

LIFE HISTORY.

As previously indicated, this species hibernates in the seed stalks of blue-grass in waste places and along fences since pastures are kept cropped so closely that there is little chance for it to winter over there. It hibernates as a larva, pupates in spring, and the adult emerges early in May. It is one of the first species to make its appearance in the spring. Males normally occur. The egg is shown in figure 8 at *e*.

THE FESTUCA JOINTWORM.¹

The Festuca jointworm was described recently by the writer and W. T. Emery (10, p. 454) from specimens reared from material collected by the writer near Youngstown, Ohio, in 1913. Since that date it has been located at other points in Ohio, New Jersey, Pennsylvania, and Virginia. It is the slenderest species among the gall formers, the abdomen being particularly long and narrow.

MANNER OF INJURY.

H. festucae forms galls or hardened enlargements, usually above the second joint from the ground, although they may occur at any joint. The galls (Pl. VI, C) may be prominent or inconspicuous; in the latter case they can be detected only by pinching the stems between the fingers. The injury undoubtedly would be serious to the seed crop and very probably would shorten the hay crop, also, as the flowering stalks are rather slender, and although not quite as frail, they are very much like blue-grass stems in that they are not woody. *Festuca* sp., therefore, would naturally suffer more from attacks of this kind than would orchard grass or timothy.

HOST PLANTS.

The writer has been rearing *festucae* from *Festuca* sp. in confinement and making observations in the field for 5 years and has not reared this species from any other host.

¹ *Harmolita festucae* Phillips and Emery.

LIFE HISTORY.

As this grass grows naturally in waste places and along fences its jointworm enemy does not depend upon cultivated areas to maintain itself. It winters in the old seed stalks as pupa, the adult emerging near the middle of May. The species is normally thelytokous, males very rarely occurring.

SPECIES INFESTING WILD GRASSES.

In the preceding pages the writer has given briefly some of the more important facts relating to all the species at present known to infest our grains and cultivated grasses. It may appear at first glance that wheat has rather more than its share of species, especially since it is our most important small grain. On the other hand, the genus *Elymus*, a wild grass, is the home of nine species, eight of which are gall-formers; *Agropyron* sp., another wild grass, has four species, three of which are gall-formers. The species infesting the wild grasses will be dealt with very briefly. A good many of them may lay a just claim to some consideration from an economic standpoint, from the fact, as previously stated, that they have parasites in common with the more important economic species.

HARMOLITA MACULATA Howard.

Howard (8, p. 15) described this species as *Isosoma maculatum* in 1896 but nothing was known then of its life history. In recent years it has been collected by various members of the branch of Cereal and Forage Insect Investigations. The writer has reared it in confinement since 1912. It has persistently refused to breed in any host other than grasses of the genus *Bromus*. It does not form galls but lives in the walls of the plant stem, particularly of cheat (*Bromus secalinus*). The cheat stem is almost solid near the base, at least just above the lower joints, the walls being very thick. The egg (fig. 8, *d*) apparently is deposited in the walls of the stem somewhat like the egg of *tritici* and the larva excavates a little tunnel about half an inch long just above the joint (Pl. V, B). There are sometimes two or three to an internode. It is a very widespread species and undoubtedly occurs wherever cheat or other species of *Bromus* are found.

There is only one generation a year. The species hibernates in the larval stage, pupates in the spring, and the adults emerge in May. It is arrhenotokous under control conditions though in nature both sexes occur.

HARMOLITA ATLANTICA Phillips and Emery.

Harmolita atlantica (10, p. 461) is a species which the writer first reared near Richmond, Ind., in 1909. A few specimens have been

taken in Michigan and many in New York. It has been reared sparingly in confinement, not being a very tractable species. It has never been reared from any host other than *Agropyron*.

This species forms galls in the stems. Some of the galls resemble somewhat those of *tritici*, being placed in the walls of the stem; others resemble those made by *vaginicola*, occurring in the sheath surrounding the head. In the latter case the head does not appear at all. (Pl. VI, B.)

There is only one generation a year, and, as with the majority of species, they pass the winter as larvæ in the galls of the old plant stems, pupate in the spring, and emerge as adults in May. The species is normally thelytokous, males rarely occurring.

HARMOLITA AGROPYROPHILA Phillips and Emery.

Harmolita agropyrophila (10, p. 450) is the only species, besides *grandis*, that has two generations a year. Singularly enough, *Agropyron* is one of the few plants infested by *Harmolita* that produce stems continuously throughout the growing season. The majority of the other jointworm species would find it difficult to maintain two generations a year on a single host unless they were dimorphic like *grandis* and one generation developed in the very young plants.

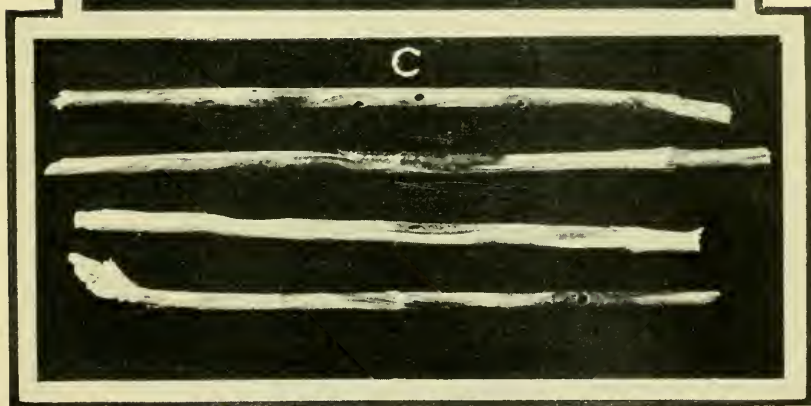
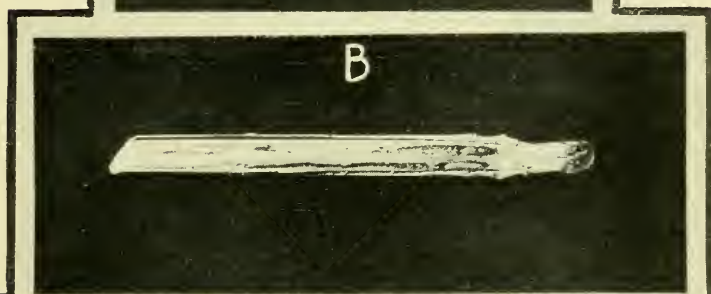
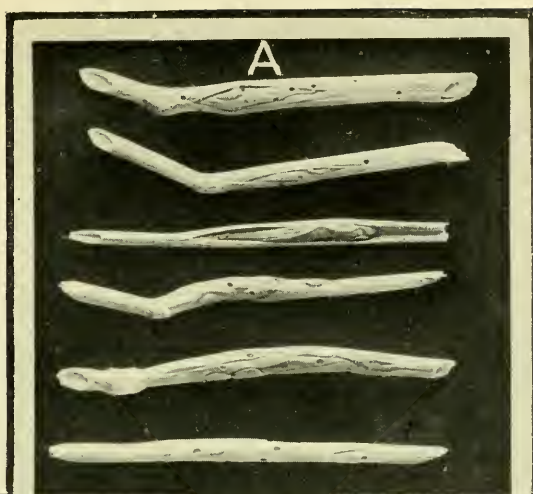
H. agropyrophila was collected first in 1904 by F. M. Webster. Since that time it has been collected by various members of the branch of Cereal and Forage Insect Investigations. The writer has been rearing and observing this species since 1905, when he first discovered that it has two generations in a year. The larvæ inhabit the center of the stem and may be found at any joint.

The species has never been reared from any host other than *Agropyron* although repeated attempts have been made to induce it to live on other plants in confinement. There are two generations a year, the first generation emerging very early, during the last week in April and the first week in May. It is one of the first species to emerge. The second generation emerges the latter part of June and the first week in July.¹ The second generation deposits its eggs (fig. 2, *g*) in the young tender stems, and as it is rather late in the season these stems do not produce heads.

HARMOLITA ELYMI French.

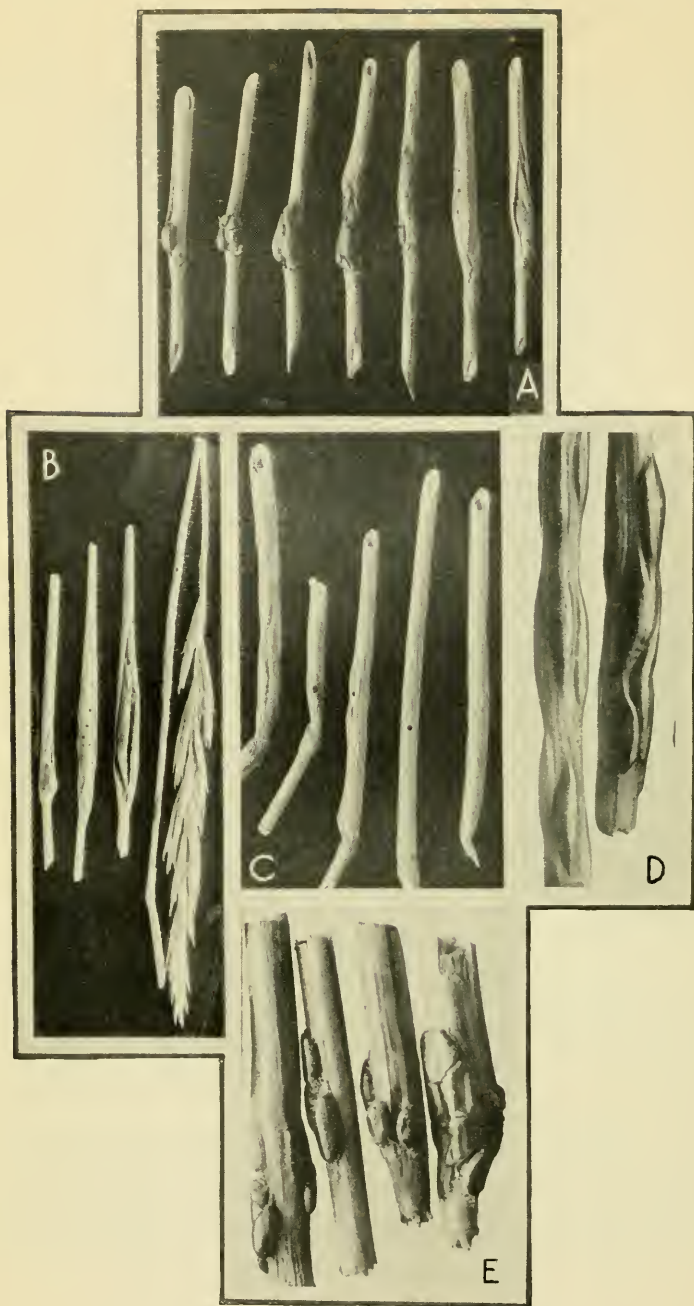
This species was described as *Isosoma elymi* in 1882 by G. H. French (6), who reared it from *Elymus americanus* from Carbondale, Ill. The writer's attention was first attracted to it in 1908, when it was learned that it occupied the center of the stem of *Elymus* sp.

¹ These dates apply to Richmond, Ind.



JOINTWORM FLIES OF THE GENUS HARMOLITA.

A, Characteristic gall of the rye jointworm (*H. secalis*) in rye (about natural size); B, larvæ of *H. maculata* in a cheat stem (about natural size); C, galls of *H. elymlvora* in *Elymus* sp. (about natural size).



JOINTWORM FLIES OF THE GENUS *HARMOLITA*.

A, Characteristic galls of *H. elymicola* in *Elymus* sp., slightly reduced; B, two types of injury to *Agropyron* sp. by *H. atlantica*, those to the left being sheath galls and the long stems to the right being stem galls, slightly reduced; C, Typical galls of the Festuca jointworm (*H. festucae*), about natural size; D, E, characteristic galls of *H. clymophthora*, enlarged slightly. (Photographs D and E by Mr. C. N. Ainslie.)

Nothing was known of its life history until recent years. It has a wide range, being found as far west as Utah, and having been reared from collections of *Elymus* from Illinois, Indiana, Ohio, and Virginia. It probably occurs wherever *Elymus* sp. grows normally.

H. elymi inhabits the center of the stem of *Elymus* sp. and has never been reared from any other plant, although repeated attempts have been made to rear it from wheat, rye, barley, and some of the grasses. There is only one generation a year. Hibernation is in the larval stage, pupation occurs in the spring, and the adults emerge in May. This species is thelytokous, males never having been observed.

HARMOLITA ELYMICOLA Phillips and Emery.

Harmolita elymicola (10, p. 460) is the commonest species on *Elymus* in the Eastern States and is apparently a strictly eastern species, as it has not been collected west of the Mississippi River with the exception of southeastern Missouri. East of the Mississippi it has been taken in Illinois, Indiana, Michigan, Ohio, and Virginia.

It forms very prominent galls or enlargements, usually above the second joint from the base of the plant (Pl. VI, A). It has never been reared from any host other than *Elymus*. Repeated attempts have been made to breed the species on wheat, barley, and various grasses. It has been observed to oviposit in wheat and barley stems, but nothing ever developed in these stems. Figure 8 c, shows eggs of this species.

H. elymicola has only one generation a year. It hibernates as a larva in the old seed stalks, pupates in the spring, and emerges in May. It has proven to be arrhenotokous under control conditions, but both sexes normally occur in nature.

HARMOLITA ELYMIVORA Phillips and Emery.

Harmolita elymivora (10, p. 464) is not nearly as abundant as *elymicola*, though it apparently has a wider range, having been found as far west as Arkansas. It has also been reared from stems of *Elymus* sp. collected in Indiana, Michigan, Ohio, and Virginia.

H. elymivora forms galls in the stems of *Elymus* sp. just below the head. As a result, the head or fruiting body of the plant never develops (Pl. V, C). It is possible that it forms galls of the *elymicola* type also, but the writer has never reared any from such galls.

The life history is similar to that of *elymicola*. Eggs are shown in figure 2, c.

HARMOLITA RUFIPES Phillips and Emery.

Harmolita rufipes has been described only recently (10, p. 453), but F. M. Webster is probably the first to have reared it. In Bulletin 42 of the Division of Entomology Prof. Webster confused this species

with *H. hordei* Harris, stating that he had reared *hordei* from *Elymus* at Champaign, Ill. The writer has examined these specimens and they are very clearly *rufipes*. The species resembles *hordei* somewhat in that the legs are reddish brown, but it is much larger than *hordei* and other characters very readily distinguish them. *Rufipes* is apparently a strictly western species, never having been reared any farther east than Champaign, Ill. It has been reared from *Elymus* sp. collected in Kansas, Nebraska, New Mexico, and Utah. It has never been reared from any grass other than *Elymus* sp. Repeated attempts were made by the writer to rear it in confinement at both La Fayette, Ind., and Charlottesville, Va., upon its host, but it has steadily and persistently refused to breed. It apparently would oviposit, but no larvæ ever developed. It forms galls in the stems of *Elymus* sp. Nothing is known of its life history further than that it has a single generation during the year, hibernating in the usual way and emerging in May. Both sexes occur.

HARMOLITA HESPERUS Phillips and Emery.

Harmolita hesperus (10, p. 457) was considered by the writer for quite a while to be *rufipes*. The two species can be distinguished, however, very readily. *H. hesperus* is apparently a strictly western species, having been reared from *Elymus* sp. collected from Kansas and Utah, but it has never been found east of the Mississippi River.

H. hesperus forms galls very much as does *elymicola*. It has not been reared from any plants other than *Hordeum jubatum* and *Elymus* sp. Nothing is known of its life history further than that it hibernates in the usual way and emerges in May. Both sexes occur normally. The writer has never been able to rear this species in confinement, though repeated attempts have been made to rear it in *Elymus* sp., both at La Fayette, Ind., and at Charlottesville, Va. The egg is shown in figure 7 at *a*.

HARMOLITA ELYMOPHTHORA Phillips and Emery.

Harmolita elymophthora (10, p. 465) appears to be a strictly western species also, having been reared only from Nebraska and North Dakota. It was first brought to the writer's attention by C. N. Ainslie, who sent in galls on *Elymus* sp. from which was reared this species. It forms galls in *Elymus* sp. (Pl. VI, D, E), though it is not known whether it has other hosts or not. It has refused to breed in confinement at Charlottesville, Va. It has one generation a year and both males and females normally occur.

HARMOLITA OVATA Phillips and Emery.

Harmolita ovata (10, p. 458) has been reared only from Kansas. It was sent to the writer in the fall of 1914 by E. O. G. Kelly, who was

then a member of the Cereal and Forage Insect Investigations force. It forms galls in *Elymus* sp. It is not known whether it has other hosts. It refused to breed in confinement at Charlottesville, Va. There is one generation a year and apparently both males and females occur.

SPECIES WHOSE BIOLOGY IS UNKNOWN.

The species previously treated in this paper have all been reared repeatedly in cages under artificial conditions with the exception of *captiva*, *rufipes*, *hesperus*, *elymophthora*, and *ovata*. The writer has never seen living specimens of the remaining six species described by Phillips and Emery (10)—*poophila*, *agropyrocola*, *occidentalis*, *elymophila*, *elymoxena*, and *gillettei*—or of *bromicola* Howard and *agrostidis* Howard, and practically all that is known concerning them is contained in the meager data incidental to collection. Four of these, *agrostidis*, *bromicola*, *elymoxena*, and *elymophila*, are from California; two, *gillettei* and *poophila*, are from Colorado; one, *agropyrocola*, from Utah; and *occidentalis* from New Mexico. Nothing, of course, is known of their life histories. *Poophila* was reared from *Poa lucida*, sent in by A. D. Hopkins from Husted, Colo.; *agropyrocola* and *occidentalis* were reared from *Agropyron* sp., the former reared from material sent in by Desla Bennion and the latter from material forwarded by V. L. Wildermuth; *bromicola* was reared from *Bromus ciliatus*; *agrostidis* was reared from *Agrostis* sp.; *elymophila* and *elymoxena* were reared from *Elymus* sp. The four last species were collected by Albert Koebele. *H. gillettei*, as the name implies, was reared by C. P. Gillette and was named for him; the host is unknown. Undoubtedly further observations and collections will add many more new species from the Western States, and more particularly from the Pacific Coast States.

CONTROL MEASURES.

Farmers, as well as entomologists, have concerned themselves very little about controlling these really serious pests. Fortunately or unfortunately, depending upon the point of view, the parasites have taken care of the situation to such an extent that only now and then the jointworm (*H. tritici*) gets out of hand and causes the almost total destruction of a crop in a given locality. Therefore the matter has been viewed very calmly and a toll of from 1 to 5 bushels or more per acre has commonly been tolerated. We have been perfectly content to pay an annual tribute in preference to fighting vigorously to throw off this burden. But for the parasites we should have been obliged to bestir ourselves long ago or else abandon wheat growing in the Eastern States. There is some excuse for this condition of

affairs, in that there was no very simple remedy at hand; for example, simply spraying the wheat would not cure the trouble.

The writer has studied the situation for years and has found that most if not all of the so-called remedies are useless. For several winters futile attempts were made to burn over stubble fields in Indiana. In the first place the ground must be frozen or the burning will destroy the young clover and at no time during the winter could the stubble be burned under these conditions. This would be the simplest of all remedies if it were practicable, although it would destroy a source of humus. Another supposed remedy was to plant wheat as far from the old stubble as possible. This is folly unless the farm in question covers an area of several square miles. The jointworm can fly and may be carried by the wind at least for a mile. The suggestion of sowing wheat early, in years of scarcity of the Hessian fly, is equally futile. V. L. Wildermuth, of this bureau, made observations on 51 fields at Groveport, Ohio, in 1909, in order to determine the effect of early and late sowings in relation to jointworm injury. Twenty-eight fields sown from September 10 to 30, with an average date of September 24, showed an average infestation of 38 per cent, with an average yield of $8\frac{1}{2}$ bushels per acre; 15 of these fields produced grain of good, 10 of medium, and 3 of poor quality. On the other hand, 23 fields sown October 1 to 24, with average date of October 10, showed an average infestation of 19 per cent with an average yield of 20 bushels per acre; 11 of these produced grain of good, 9 of medium, and 3 of poor quality. These observations show also that whether the wheat were sown early or late the wheat on poor ground always was infested to a greater degree, provided the fields were equally distant from the source of infestation. The writer's observations confirm this idea.

Some writers have suggested that the larvæ would be destroyed if the infested stubble should pass through stables and then be subjected to the process of decomposition incidental to composted manure. The writer therefore placed infested stubbles in horse stables and allowed them to become mixed with the droppings in the ordinary way. They were then removed to the center of a heap of manure and part of them allowed to remain in the manure all winter while the remainder were removed after having remained in it for two weeks, and then scattered on the ground and allowed to remain there undisturbed throughout the winter and spring. Those remaining in the manure pile were removed the last week in March, and placed in confinement for observation, as were those that were scattered on the ground in early winter. Each lot produced about the same number of adults as did stubble that was allowed to winter in the usual manner in the field. This experiment certainly indi-

icates that there is small hope of destroying the jointworm by passing infested straw through the manure pile.

The writer has been experimenting for the past three years in plowing under wheat stubble for the purpose of observing the effect on infestation the following year in wheat planted on the same ground. This work was done in the vicinity of Charlottesville, Va., where no infestation occurred nearer than 5 or 6 miles. Therefore the data secured should be reliable, as there was no opportunity for the jointworm to come in from neighboring fields. Small plats were used and the infestation was accomplished by bringing in a very large amount of infested stubble from a distance, placing it in the growing wheat, and allowing the adults to emerge and infest the plat. In order to insure heavy infestation, large amounts of badly infested stubble were brought in again from a distance after the wheat was cut, making accurate counts of the number thus brought in, and then carefully estimating the infestation that already existed on the plat. The total number of wheat stems or stubbles was then counted on several representative square yards of the plat. In this way the percentage of artificial infestation could be determined accurately. The infested stubbles which had been introduced, together with the stubbles already standing on the plat, were then turned under. The ground was plowed as soon after harvest as possible, disked, and some crop like peas or soy beans sown. The plat was disked again in the fall at the proper time and reseeded to wheat. In this way an 8 per cent infestation was reduced to 1 per cent the following year. A second trial reduced the infestation from 32 per cent to 3 per cent. A third trial in 1918 reduced a 19 per cent infestation to 2 per cent.

These experiments indicate that plowing under stubble is a very effective remedy. It doubtless would destroy all of the insects if all of the infested stubbles could be completely buried, but it is impossible to do this. Nevertheless it is practicable to control the ravages of the species in this manner. While this method of control would necessitate a change in the existing rotation of crops where wheat is used as a nurse crop for clover, it would seem that it should be adopted if millions of dollars could be saved every year in this manner. Some agronomists admit that it would be practicable to change the existing system of rotation so as to permit plowing down stubble to suppress important insect pests. If this were done not only the jointworm but also the Hessian fly would be controlled, and thus two of the major insect pests of wheat would be largely shorn of their power for harm to our most valuable bread grain.

The barley jointworm, the rye jointworm, and the rye straw-worm undoubtedly can be controlled in the same manner, if the necessity arises.

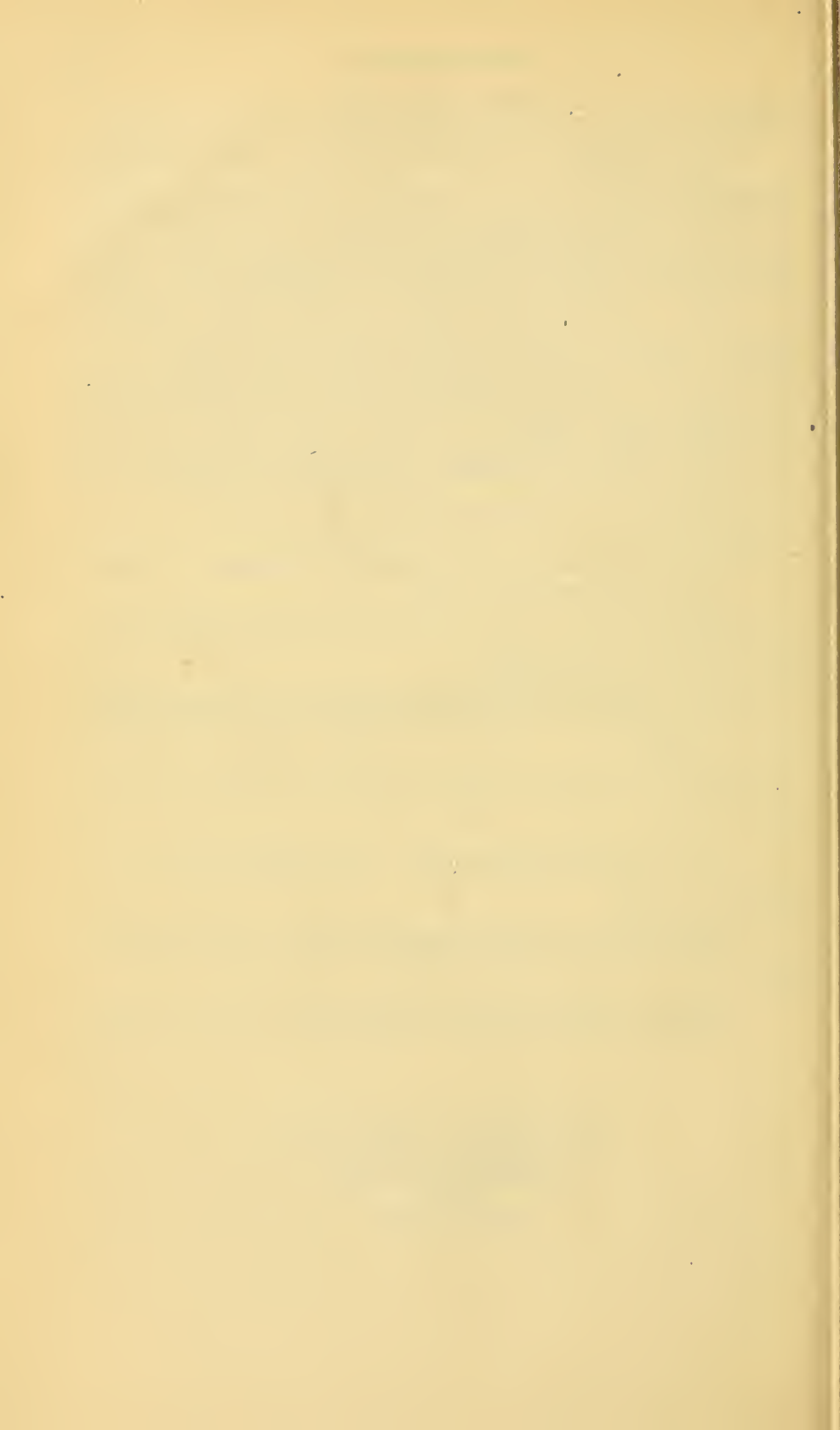
The wheat straw-worm is very easy to control. Since one generation is wingless it is only necessary to keep down all volunteer wheat and never plant wheat nearer than 40 to 50 yards to infested stubble. This is allowing a wide margin of safety since they are supposed to be able to travel at most only 12 or 15 feet.

Should it become necessary to control the straw-worms and jointworms infesting our cultivated grasses, such as timothy, orchard grass, blue-grass, and *Festuca* sp., this undoubtedly could be accomplished by clipping such fields in the spring in order to delay the appearance of seed stalks until the emergence of the insects, when there would be no place for them to deposit their eggs.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 809

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.

PROFESSIONAL PAPER

March 10, 1920

AMERICAN FOULBROOD

By

G. F. WHITE

Specialist in Insect Diseases

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INTRODUCTION

American foulbrood is an infectious disease of the brood of bees caused by *Bacillus larvae*. The disease is characterized by a decided ropiness of the decaying brood and a peculiar foul odor. It is very widely distributed, is readily recognized, and is of much economic importance. Its existence has been known for a long time, and beekeepers have established many facts concerning it through observations made while practicing their profession. While there is a consensus of opinion among beekeepers on certain points regarding the disorder, there are others on which a diversity of views has existed and still others about which almost nothing of a definite nature has been known.

Former work was directed primarily toward the determination of the cause of the disease. Among the problems considered in the present studies are: The resistance of *Bacillus larvae* to heat, drying, sunlight, fermentation, and disinfectants; the effect of the disease on the colony and on the apiary; and the transmission, diagnosis, and prognosis of the disease. Direct studies on the treatment of the

disease have not been attempted by the writer. It will be readily recognized, however, that any treatment that is efficient and at the same time economical must be determined by results obtained by the solution of such problems as those which have received attention in these studies.

The facts may tend to engender fear for the disorder in some instances while in others they may tend to allay it and to offer encouragement. It is hoped, however, that no statement made here will cause any beekeeper to lessen the vigilance that the disease requires, nor, on the other hand, to increase it to a point that would render its control uneconomical.

The discussions in the present paper are based almost entirely upon observations made in the laboratory and in the experimental apiary. The value of the results is emphasized by the fact that the disease produced experimentally and the disease encountered in nature are identical in almost every respect. It is believed that the paper¹ will be of interest not only to the practical beekeeper who wishes to apply the results noted here in the practice of his profession, but also to those who may desire to make further studies on the disease.

NAME OF THE DISEASE

That bees suffer from diseases is recorded in works written before the Christian era but it is not altogether clear what the diseases were. In 1771, Schirach (19)² was using the term "foul brood" for an abnormal condition of the brood of the bees, but from his conception of the cause of the disorder one is led to believe that more than one abnormality was being referred to by the term. In 1882 Dzierzon (11) had definitely concluded that there were two kinds of foulbrood. Cheshire expressed a similar belief in August, 1884, but by September he had reached the conclusion that there was but one.

In 1885 Cheshire and Cheyne (9) published an article containing the results of some studies on foulbrood including a description of *Bacillus alvei*. For more than a decade after the appearance of the paper, the view was quite generally accepted that there was but one disease present in the condition that was being called foulbrood and that *B. alvei* was the cause of it. Many American beekeepers, those in New York State especially, became convinced, some time during the decade from 1890 to 1900, that two serious brood diseases were being referred to by the one name—foulbrood.

That there are two such diseases has been conclusively proved. In the United States the one characterized by a decided ropiness of

¹ The studies reported in the present paper are similar in nature to those made by the writer on sacbrood (25), Nosema-disease (26), and European foulbrood (27). These papers may be helpful where the discussions in the present one are especially brief. The investigations were completed in September, 1916, and the paper was submitted for publication in October, 1918.

² Figures in parenthesis refer to "Literature Cited," p. 42.

the decaying brood and a peculiar foul odor is now called American foulbrood, and the other one which is not so characterized is called European foulbrood. These two foulbroods are very different, the principal point of similarity being that they are both brood diseases. Both of them occur in Europe as well as in America. Unless these facts are borne in mind the names are likely to be misleading.

The term "foulbrood" (French, *la loque*) in most countries as in America frequently is used in a general sense meaning simply some disorder of bees but no definite disease. In this popular use of the term, either or both of the two foulbroods may be meant. Other brood disorders sometimes are loosely referred to by this general term. "Foulbrood" and "bee pest" or slight modifications of these terms as used in different countries certainly include the disease American foulbrood. In Switzerland no pronounced odor had been observed in connection with American foulbrood and it is referred to as "nichtstinkende Faulbrut" (6, 7, 8); in Austria it is called "Faulbrut" (18); in Germany "Brutpest" (29) and "Faulbrut" (12); in Denmark it is called "Bipest" (2, 3, 4); in England (10) and in Ireland it is called foulbrood or bee pest; and in Australia it is called foulbrood (5).

There are at least three infectious brood diseases of bees but as a rule the one which beekeepers, entomologists, and pathologists have referred to in the past by the term "foulbrood" is the disease American foulbrood, discussed in the present paper.

HEALTHY BROOD AT THE AGE AT WHICH IT DIES OF AMERICAN FOULBROOD

The description of the symptoms of a brood disease as well as the recognition of the disease are very materially aided by making a comparison of diseased with healthy brood. Such a comparison involves the age of the brood, the relative arrangement of the capped and uncapped cells, the appearance of the diseased and of the dead brood, and the relation of the dead larva or pupa to the cell in which it lies. Furthermore, the character of the caps and the odor of the brood-combs should not be overlooked.

In healthy brood-combs a certain regularity is to be expected in the arrangement of areas containing eggs, larvæ, pupæ, and emerging brood, respectively. The cell caps when recently constructed are convex outward (Pl. II, A), but usually become flattened somewhat before the bees are ready to emerge. They are rarely punctured, remaining as a rule entire. In color these combs vary widely from a very light hue when recently constructed to a dark brown when old. Accompanying them is a slight but not disagreeable odor.

In American foulbrood the brood that dies does so nearly always either during the last two days of the four-day prepupal period or

the first two days of the pupal period. Such brood, therefore, is in capped cells. A description of a healthy larva at this age is given by the writer in a paper on sacbrood (25) and will be recounted here only briefly.

A larva (prepupa) (Pl. II, D, G; Pl. VI, G), at the age at which death from American foulbrood takes place as a rule, lies extended lengthwise in the cell with its dorsal side against the floor. It is motionless with its head in the direction of the mouth of the cell, its extreme anterior end extending nearly to the cap at the angle formed by the cap and the roof. Its posterior third lies upon the bottom of the cell and extends to the roof; its length is approximately that of the cell, being about one-half of an inch; its width is that of the cavity of the cell, about one-fifth of an inch; and its two lateral sides cover about one-half each of the two lateral walls of the cells. The ventral surface of the larva is in general convex from side to side and concave from end to end. Transverse ridges and furrows give a segmented appearance to the body. An empty space of considerable extent occurs between the ventral surface and the roof of the cell (Pl. VI, G).

The color of the larva at this time is almost white with a slight bluish tint. The entire surface is glistening. The body wall is sufficiently resistant to permit the removal of the larva intact if care is exercised. The tissue mass as seen when the body wall is ruptured is semiliquid and nearly white in appearance. Upon microscopic examination it is found to be made up very largely of fat cells, and to be free from bacteria and other microorganisms.

The change from the larva to the pupa (Pl. VI, B), as far as outward appearances are concerned, takes place rapidly. Infrequently death from the disease takes place during this short period. At this time the bee (Pl. VI, B) has neither the outward form of a larva nor of an adult. This stage of the transformation is recognized by the fact that the head is smaller than that of the complete pupa and the appendages are largely wanting.

The pupa (Pl. IV, A, D) immediately after transformation is similar in form and size to the adult bee. It rests with its back against the floor of the cell and with its antennæ, proboscis, and legs lying along its ventral surface. The posterior third is more pointed and much smaller than the same third of the larva. It lies upon the bottom of the cell but does not extend to the roof.

The color of the pupa at the time of its transformation is nearly white with a slightly bluish tint. The first pigment observed is seen in the compound eyes. Pigmentation of other parts of the body follows. When death from American foulbrood takes place, it does so almost invariably before the time that pigmentation of the body other than of the eyes has occurred. The body wall of

the healthy pupa for the first two days of this stage is easily ruptured. Its tissues are soft and when crushed are creamlike in consistency. During this period some care must be exercised in removing the body intact. Soon the body wall toughens so that the form is then maintained rather rigidly.

SYMPTOMS

Much of our knowledge concerning the symptoms of American foulbrood has been gained through observations made by beekeepers while practicing their profession. The apiary in which the disease has been produced by experimental inoculations offers an opportunity to obtain a fairly complete picture of the disease. The present discussion of symptoms of the disorder is based upon observations made on the disease thus produced. During these studies it has been possible to duplicate observations already made by beekeepers on the disease as it occurs in nature and to make still others. It is quite probable that a number of these additional observations could be duplicated on the disease in nature if a sufficiently close study were made.

GENERAL SYMPTOMS

In American foulbrood the symptoms vary within wide limits. The colony may or may not be noticeably weakened. If recently infected the strength will not be affected appreciably, but if the infection has been present for a considerable period the colony will be weakened as a rule. Not infrequently during the course of the disease the strength of the colony is diminished and death is the result. Between these limits any degree of strength may be encountered.

The occasional larva which dies of American foulbrood (Pl. VI, A) before it reaches the age at which healthy larvæ are capped rarely, if ever, is capped after its death. Aside from these few larvæ the brood that dies of American foulbrood does so in capped cells. After death the caps are removed by the adult bee from a large but varying proportion of cells containing dead brood (Pl. III, C, F, I; Pl. V, B), although they are allowed to remain on a considerable proportion of them (Pl. VI, C, E, F; Pl. II, B, C, E, F, H, I; Pl. III, A, B, D, E, G, H; Pl. IV, B, C, E, F; Pl. V, A, C, D, E, F). The irregular condition of the brood comb sometimes referred to by beekeepers as the "pepperbox" appearance (Pl. I, A, B, C) is due very largely to the presence of cells containing dead brood which have been uncapped by the bees, occurring among similar cells which have not been uncapped, together with cells containing healthy brood either capped or uncapped.

The caps over dead brood (Pl. II, B) appear in many instances similar to those covering healthy brood. In many instances,

however, they are altered, being sometimes punctured (Pl. III, A; Pl. VI, C), sometimes sunken, and sometimes darkened. Sometimes these abnormal appearances are combined. The holes in the caps vary in number and dimensions. Ordinarily there is but one (Pl. III, A), although there may be two (Pl. VI, C) or more. They are usually the size of a pinhead or smaller. The puncturing of the caps is done by the adult bees, and at the time of observation any proportion of the cap may have been removed.

Sunken caps are found only after the disease has been present in the colony for a considerable period, weeks at least. This symptom is most marked after the brood frames have been roughly handled, as in shaking bees from them or shipping them by express or mail (Pl. I, C). This condition of the caps is encountered more frequently in samples shipped to the laboratory than in those taken directly from the affected colony. By rough handling the viscid decaying mass within the cell is brought in contact with the cap, adheres to it and tends to draw the cap inward as it settles, accounting in a large measure for the condition referred to as sunken cappings. The dark caps occur somewhat later and also depend largely upon the presence of decaying brood material within the cell. The caps of many cells containing dead brood, however, are neither sunken nor darkened by its presence.

When recently dead the decaying brood in American foulbrood is light brown in color, the shade deepening as the process of decay continues. The color passes through a chocolate, coffee, and mahogany brown, reaching a very dark shade as it approaches the scale stage.

The body wall of a larva or pupa dead of the disease soon softens and is easily ruptured, making it impossible to remove the remains intact from the cell. As the process of decay continues the mass becomes viscid and before the scale stage is reached the viscosity is such that it is capable of being roped out into fine threads to a distance of 2 or 3 inches and sometimes even more. The scale when dry adheres more or less firmly to the cell wall.

The odor of the brood combs, when it is present, is characteristic of the disease and may be spoken of conveniently as the foulbrood odor. It is never detected in the early stages of the disease and if only scattering cells are present seldom is noticed. When much brood is dying and the disease has been present for weeks, the odor is noticeable and sooner or later becomes marked. When marked it is recognized by its strong and penetrating character and is usually thought of as being disagreeable. The brood combs after their removal from the hive tend to lose this foulbrood odor. The presence and extent of it in samples of the disease vary considerably, the variation depending largely upon the facts just mentioned.

It is possible to recognize most cases of American foulbrood from the general symptoms that are present. On the other hand many cases can be diagnosed only by an exact knowledge of the postmortem conditions of brood dead of the disease. A close study of these appearances, therefore, is advisable. The following somewhat brief description of larvæ and pupæ dead of the disease will suffice in most instances and will serve as a guide to further observations.

SYMPTOMS MANIFESTED BY THE BROOD

Signs that will determine the exact time of death from American foulbrood have not yet been ascertained. As the larvæ and pupæ that die of the disease do so at a period in their growth when healthy brood is motionless, lack of motion is no guide. In the descriptions made in the present paper it is assumed that a larva or pupa is dead if it shows a change from a bluish-white, more or less transparent appearance to one that is more nearly white, more nearly opaque, and shows at the same time a change from the normal turgidity to a slightly flaccid condition.

The appearance of the larval and pupal remains changes gradually from day to day from that of a healthy brood to that of the dried residue—the scale. A description, therefore, that would be correct for one day would be incorrect probably for the following day. Furthermore, all of these remains do not pass through the same changes. For convenience in description, therefore, the various appearances assumed by them are considered in five more or less arbitrary stages. The interpretation of the descriptions will be aided if the description of healthy brood (p. 3) is borne in mind, since the terms used are similar in both instances.

LARVÆ DEAD OF AMERICAN FOULBROOD

The descriptions made of dead larvæ (prepupæ) for the most part will be of those that have died during the 2-day quiescent period just preceding the transformation to the pupa, as most larvæ dying of the disease succumb at this age.

FIRST STAGE

The first symptoms of American foulbrood appear about the end of the first week after infection. From the bluish white of the healthy larva the color changes during this first stage of the disease to a very light brown. The conelike anterior third (Pl. II, E) having settled somewhat, the apex is now slightly farther from the roof. The surface markings in each of the three thirds (Pl. II, H) are very similar to those of a healthy larva. The body wall is easily ruptured, but by care the larva may still be removed intact from the cell. In consistency the decaying tissues are soft and nonviscid.

Sometimes a considerable portion of a larva is removed piecemeal by the bees during the first stage of decay. The remnant (Pl. VI, D), consisting of the posterior third and usually much of the middle third, is found occupying its normal position in the cell. The surface markings are similar to those of the middle and posterior thirds in the first stage of decay. The surface left by the removal of the fragments is somewhat roughened and transverse to the body. These larval remnants are similar to those seen in sacbrood, but in American foulbrood there are fewer of them. When present they form one of the earliest symptoms of the disease.

SECOND STAGE

By the second week after death the larva shows a slightly deeper shade of brown, although still quite light. The anterior third (Pl. II, F) is somewhat darker than the other two thirds. The apex is farther from the roof than in the first stage. The surface markings (Pl. II, I) are now less pronounced throughout. An attempt made at this time to remove the dead larva from the cell results usually in rupturing the body wall. The decaying mass can be entirely removed, however. The consistency of the tissue mass in this stage is somewhat similar to that of moist dough. It has not yet reached the true viscid condition.

THIRD STAGE

By the third week after death the remains have assumed a medium shade of brown, approximating that usually seen in brood cappings. The apex of the anterior third (Pl. III, D) is now widely separated from the roof of the cell, exposing to view the ventral surface of the remains. The transverse ridges and furrows marking the segments (Pl. III, G) are practically obliterated. The edges no longer show the deep notches. The side-to-side convexity is decreased. Evidences of developing head and thoracic appendages are sometimes seen. Transverse tracheæ can usually be observed as white lines across the ventral surface of the abdomen, one in each segment. The body wall is ruptured easily. The decaying mass shows some viscosity and adheres to the walls of the cell.

FOURTH STAGE

By the fourth week after death the color of the dead larva reaches a deep brown, being in shade similar to that of the average older brood combs. The apex of the anterior third (Pl. III, E) is raised only slightly above the upper surface of the decaying larval mass. After being uncapped this third is the first to dry, becoming dark and scale-like. Surface markings practically have disappeared; tracheæ frequently are still visible, especially in the middle third. The ventral

surface (Pl. III, H) is now slightly concave from side to side. The posterior third lies upon the bottom of the cell and extends to the roof. The decaying larval mass is now decidedly viscid in consistency. When tested with a toothpick, match, forceps, or any other suitable object it can be drawn out into threadlike strings. This viscid condition of decaying brood is referred to by beekeepers as "ropiness." It is a well known symptom and is much used in the diagnosis of the disease.

FIFTH STAGE

One month or longer after the death of the larva the remains are found to be a thin mass more or less dry and covering most of the floor, some of the side walls, and the bottom of the cell. The dried mass is known to beekeepers as the "scale." Its color is dark brown, similar to that of old brood comb. That portion which was once the anterior third of the larva bears, if at all, only a slight elevation (Pl. III, C, F, I; Pl. VI, E, H). The ventral surface (Pl. III, I) is concave from side to side and quite uniform. The posterior third covers the bottom of the cell and extends to the roof. This can be seen especially well by cutting lengthwise the cell with a scale (Pl. VI, H) in it. It can be seen also that the thickness of a scale throughout the median line is approximately uniform.

As some larvæ die of American foulbrood before the quiescent stage is reached but after being capped, their dead remains may be found occupying not the uniform position just described but various positions in the cell. While the form of the remains, therefore, may vary materially, the color and consistency pass through stages that are similar in all instances.

Occasionally death from American foulbrood takes place while the larva is still younger, i. e., before the time of capping has arrived and while it (Pl. VI, A) is coiled in the cell. This condition is comparatively rare. As the form of the remains depends upon the age of the larva at the time of its death, naturally, the form of the remains of a larva dying before the time for capping will vary materially from the descriptions above. The color and consistency of such a larva during its decay, however, pass through stages that are similar to those already described.

PUPÆ DEAD OF AMERICAN FOULBROOD

Death from American foulbrood does not take place late in the pupal stage but almost always, if not invariably, within the first 2 days after transformation from the larva (prepupa). At this stage the healthy pupæ are practically white, with or without pigment in the compound eyes. Pupæ dead of the disease resemble in color and consistency larvæ dead of the disease. The dead pupæ, as in the case of the larvæ, are described here in five stages.

FIRST STAGE

During the second week following the infection, symptoms of American foulbrood may be seen in pupæ. The cell containing a dead pupa is generally found capped at this time. Upon uncapping, the anterior third (Pl. IV, B) of the pupa will be recognized as resembling very closely that of a healthy one. The surface markings in general (Pl. IV, E) are not particularly unlike those of a healthy pupa. The turgidity is slightly less and the body is to a slight degree more nearly opaque. The body wall is easily ruptured and the tissue mass is soft but not viscid. In general the consistency is similar to that of a larva in the first stage of decay.

SECOND STAGE

The process of decay continuing, the tissues soften and the pupal mass settles, distorting its form. The anterior third (Pl. IV, C) has settled to the floor of the cell and is separated from the roof by a considerable distance. The face is directed more nearly upward. The surface markings (Pl. IV, F) of each third are less distinct. The legs and other appendages rest upon the body. The body wall is at this time very easily ruptured and the tissues are soft. The color and consistency are similar to those of the second stage of decay of the larva.

THIRD STAGE

During the third stage the appendages are less easily distinguished; as they settle they merge more or less with the decaying mass of the head, thorax, and abdomen. One exception should be mentioned. Some of the mouthparts (Pl. V, A), chiefly the proboscis, adhere to the roof of the cell. This condition has often been noted by the beekeepers. The face of the pupa in this stage is directed still more nearly upward than in the preceding stage. The head is not infrequently found to be disfigured through drying or being gnawed or both. The ventral surface of the middle third (Pl. V, D) is still, in general, convex from side to side. The color and consistency are similar to those of the same stage in the larvæ. When the pupal mass is removed white lines may be seen in it. These are tracheæ.

FOURTH STAGE

In the fourth stage evidence of drying is marked and pupal remains are changed still further. The anterior third (Pl. V, B) bears only a slight resemblance to that of the pupa. Through settling of the mass and through drying it is now very much flattened. The ventral surface of the middle and posterior thirds (Pl. V, E) are still slightly convex from side to side and are roughened, due chiefly to the remains of the legs and other appendages. The color of the decaying mass in the fourth stage is a dark brown similar to that

of old brood comb. This mahogany-hued mass is viscid in consistency, showing the ropiness that characterizes brood dead of American foulbrood.

FIFTH STAGE

Finally after a few weeks of decay and drying there is to be found in the cell the more or less dry residue of the dead pupa—the scale (Pl. V, C, F; Pl. VI, F, I). It covers most of the floor and some of the side walls and only a portion of the bottom. The pupal scale is in many respects similar to the larval scale. It is concave from side to side. The ventral surface is slightly roughened by the dry decayed appendages. The posterior third extends only slightly upon the bottom of the cell. This can be demonstrated by cutting the scale (Pl. VI, I) lengthwise as it occupies its position in the cell. The scale is dark brown resembling in shade that of old brood comb. It adheres rather firmly to the cell but with care can be removed from it. When thoroughly dry and removed it is found to be quite brittle.

ETIOLOGY

PREDISPOSING CAUSES

Age.—American foulbrood infection takes place only during the feeding stage of larvæ. Death occurs almost invariably after the feeding stage is passed, i. e., after capping, and either while in the larval stage or soon after transformation to the pupa. Older pupæ do not die as a result of the disease and adult bees do not become infected.

Sex.—That worker, drone, and queen larvæ are all susceptible to the disease has been demonstrated during these studies. Affected drone brood is encountered less often in the diagnosis of this disease than in that of European foulbrood. The writer has encountered queen larvæ affected by American foulbrood in experimental colonies only, although very probably diseased queen larvæ do occur in nature also.

Race.—Thus far no race of bees has been shown to possess complete immunity from the disease. In the experimental inoculations recorded in the present paper bees mixed with Italian blood were used for the most part. The queens in many of the colonies were purchased as “untested Italians.” At least five colonies of “tested Italians,” two of “tested Carniolans,” and two “tested Caucasians” were inoculated. Among the colonies used there were also several common black bees. The disease was readily produced in all of these strains. Furthermore, the results obtained from the examination of numerous samples of diseased brood received from beekeepers throughout the United States indicate that all strains of bees commonly found in American apiaries are susceptible to infection with American foulbrood. No definite conclusion can be drawn at the present time regarding the relative immunity possessed by the different races.

Climate.—It is quite well known that American foulbrood is very widely distributed. The writer has examined samples of the disease from England, France, Germany, Switzerland, New Zealand, Canada, Cuba, and various parts of the United States. This is sufficient to show that the disease exists under a great variety of climatic conditions. The practical import of the observation is that the presence of American foulbrood in any particular locality can not be attributed entirely to the climatic conditions of the region.

Season.—In general the losses from American foulbrood occur later in the bee season than do losses from either sacbrood or European foulbrood. Experimental inoculations have shown that the larvæ of bees are susceptible at all seasons and that the disease can be produced whenever brood is being reared. It would seem, therefore, that the severity of the disease is due more to environmental conditions existing at the different seasons than to any difference in the susceptibility of the larvæ during these periods.

Food.—Since American foulbrood occurs in such widely different localities (see "*Climate*"), wherein the food of bees varies almost as much as it is possible for it to vary, it may be concluded that the quality of the food used by bees has very little, if anything, to do in the causation of the disease. Furthermore, it is found experimentally that the disease can be produced when the colony is well supplied with food, when there is a moderate quantity present, or when there is a scarcity. It would seem from the facts at hand that the course of the disease probably is governed to some extent indirectly by the quantity of food present and to a less degree, if at all, by its quality. The value of these factors has not been determined but it is certainly not great in either case.

EXCITING CAUSE

During the period from 1885 to 1902 (p. 2), *Bacillus alvei* was assumed quite generally to be the exciting cause of foulbrood. From 1902 to 1907 much interest was manifested in the problem relating to the cause of the foulbroods. This is shown by the investigations of Lambotte (13) in Belgium, Burri (6, 7) in Switzerland, Bahr (2) in Denmark, Maassen (14) and Erne (12) in Germany, and those of the writer.

The writer's experience with the bee diseases began in 1902 when he was working under the direction of Dr. V. A. Moore. In the first studies made, spores were found in very large numbers in the scales of the rosy foulbrood. As these did not grow on the media commonly used in a laboratory (17) it was at once recognized that they were not the spores of *Bacillus alvei*. Furthermore, as *B. alvei* was not found in any of the samples of the rosy disease, the conclusion was drawn very naturally that this bacillus could not possibly be its cause.

Bacillus alvei was found to be present, however, with much regularity and in great numbers in the brood disease that is not charac-

terized by ropiness and foul odor—European foulbrood. These observations taught, therefore, that *B. alvei* was not to be associated with American foulbrood—the ropy, foul-smelling disease—but with European foulbrood, which does not possess these characteristics.

After beekeepers had convinced themselves that there were two foulbroods, one with a peculiar foul odor and showing a marked ropiness of the dead brood and the other without these characters, *B. alvei* unfortunately remained in the literature as the cause of the ropy, foul-smelling disease. This fact accounts for not a little of the confusion that has existed in connection with the brood diseases. It should be remembered that *B. alvei* is not the exciting cause of any bee disease.

The writer found (20) that the spores which had refused to germinate on the media ordinarily used in the laboratory would germinate and the bacillus would grow in an agar medium in the preparation of which bee larvæ were used. Satisfactory cultures for experimental purposes were not obtained with this medium, however. Later he (23) succeeded in devising a medium (p. 18) by the use of which pure cultures of *Bacillus larvæ* suitable for experimental work could be obtained in abundance and with such cultures American foulbrood was produced by inoculation, the experimentally produced disease manifesting symptoms that are typical of American foulbrood encountered in nature.

BACILLUS LARVÆ

Bacillus larvæ, the cause of American foulbrood, had been seen by microscopists doubtless long before it was cultivated successfully in the laboratory. The species requires special media for its cultivation. Success in the germination of its spores was attained in 1903 on an agar made from bee larvæ. Pending more definite information regarding the bacillus the writer (20) referred to it by the term, *Bacillus* "X." Further knowledge concerning the species was gained during the summer of 1904, and it was given the name *Bacillus larvæ* (White 21, 22). Burri (6) in Switzerland, working on the disease entirely independently, also recognized the fact that the spores present in such large numbers in the scales represented a new species that was difficult of cultivation. Maassen (14) has referred to the species as *Bacillus brandenburgensis*, and Cowan (10) has referred to it as *Bacillus burrii* (8).

Occurrence.—*Bacillus larvæ* occurs in the brood of bees dead of American foulbrood and where contaminations with such material have taken place.

Morphology.—The vegetative form is a slender rod with ends slightly rounded and with a tendency to grow in chains (fig. 1; Pl. VII, A). It varies markedly in length, depending largely upon the medium used in its cultivation. On the surface of brood-filtrate agar it is more often from 2.5 to 5 μ in length and about 0.5 μ in breadth. In a liquid medium it is usually much longer, becoming then frequently filamentous in character. During the vegetative stage the bacillus undergoes changes (fig. 5; Pl. VII, E, F, G, H) seldom noted for the bacteria. The rod possesses numerous flagella which are peritrichic in arrangement (fig. 2; Pl. VII, C).

Giant whips.—Giant whips occur (fig. 6; Pl. VII, F, G, H) in large numbers, being found especially numerous in the water of condensation of brood-filtrate agar cultures. These corkscrewlike structures vary widely in their dimensions from scarcely visible coiled filaments to bodies several micra in diameter.

Motility.—The bacillus is moderately motile in young cultures taken from the surface of brood-filtrate agar but is somewhat more sluggish when grown in liquid cultures.

Spore formation.—On brood-filtrate agar evidence of spore formation is present about the third day. The rod is swollen near the center where the spore is formed, being then spindle-shaped (fig. 3; Pl. VII, B). In a few days numerous spores free



FIG. 1.—*Bacillus larvae*: Vegetative form.

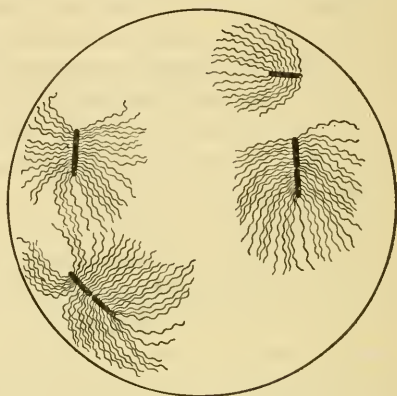


FIG. 2.—*Bacillus larvae*: The flagella.

from the rods are to be seen (fig. 4; Pl. VII, D). They measure about 0.6 by 1.3 μ . In some environments few or no spores are produced. This occurs in liquid media, deep in solid media, and on media containing glycerin, mannite, or glucose. Some of the other sugars and also honey inhibit spore formation.

Staining properties.—The rods color readily and uniformly with the analine stains, and are Gram-positive. The spores are quite resistant to stains.



FIG. 3.—*Bacillus larvae*: Spore formation.

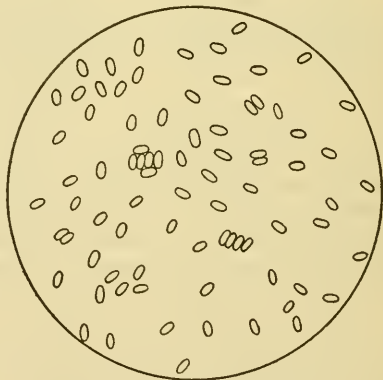


FIG. 4.—*Bacillus larvae*: The spores.

Oxygen requirements.—When bee larvæ agar alone is employed and inoculations are made with spores following Liborius' method for anaerobes, growth as a rule has appeared more often near to than on the surface (Pl. VIII, E, F, G, H, I). Subcultures on brood-filtrate agar (Pl. VIII, D) and egg-yolk-suspension agar or their combination yield abundant surface growth.

Agar slant.—On the surface of inclined brood-filtrate agar subcultures (Pl. VIII, D) grow rapidly, producing a moderate to heavy growth in 24 hours. This growth tends

to spread somewhat from the area inoculated, is grayish-white, and slightly viscid. It presents a more or less uniform border, a smooth surface, and a ground-glass appearance. Older cultures are less prominent than the younger ones.

Agar plates.—Colonies on the surface of agar vary in size depending upon the number present. When only a few are present not infrequently they spread and attain a diameter of a centimeter or more. The border is clearly defined and uniform. The growth is only slightly raised and has a smooth surface and a ground-glass appearance (Pl. VIII, A, B). Deep colonies vary from lenticular to irregular in form with filamentous outgrowths from portions of their surface (Pl. VIII, A, C).

Fermentation.—Carbohydrate liquid media as ordinarily prepared are not suitable for the growth of *Bacillus larvae*. In some of these after a considerable period a slight growth may appear at the bottom of the tubes. A little brood-filtrate or egg-suspension

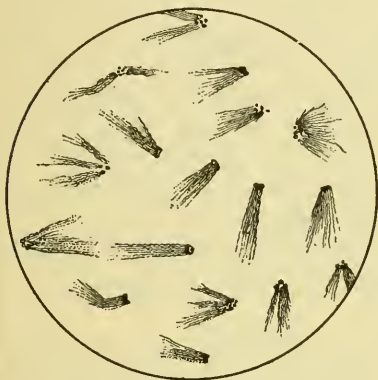


FIG. 5.—*Bacillus larvae*, illustrating an interesting feature of the organism.



FIG. 6.—Giant whips from cultures of *Bacillus larvae*.

added to the media improves it. No visible gas is formed but in some instances slight acidity is produced.

Gelatin.—No growth takes place in plain or in brood-filtrate gelatin at temperatures at which it remains congealed.

Power to resist disinfectants.—The spores of *Bacillus larvae* are very resistant to heat. When suspended in water the more resistant ones require as much as 100° C. maintained for 11 minutes to destroy them and when suspended in honey require a half hour or more (p. 22). They resist respectively 5 per cent carbolic acid for months; 1 to 1,000 mercuric chlorid for days; 10 per cent formalin for hours; and 20 per cent formalin for minutes; each acting at room temperature.

Pathogenesis.—*Bacillus larvae* is pathogenic for the brood of honeybees. Infection takes place during the feeding period of the larvæ by way of the alimentary tract. The brood dies of the disease in the larval, prepupal or early pupal stages. The earliest symptoms to be observed following inoculation usually occur in prepupæ during the seventh day after the feeding, rarely earlier. The earliest evidence of infection in pupæ occurs one or two days later. The bacilli are at this time distributed throughout the body. Adult bees, rabbits, guinea pigs, and rats are not susceptible to infection with the parasite.

While the dead brood in the scale stage and in other later stages of decay in American foulbrood invariably contains spores of *Bacillus larvae* in immense numbers, a microscopic examination of earlier stages shows not only few spores but also a comparatively small

number of rods. A partial explanation at least of this rather unexpected fact was gathered from the study of the organism on artificial media. Here it was found that the rods at times undergo interesting but as yet undetermined changes. On glucose and other media, when the growth is luxuriant and the spore formation is very much inhibited, it is noted that in older cultures rods are comparatively few in number but in their stead are forms which are neither rods nor spores but are small, more or less spherical bodies (Pl. VII, F, G, H). The exact transformation that has taken place in the bacillus to produce these bodies is not known. Something of the phenomenon has been learned through a study of the rods stained with a flagellar stain employing in the method a light aqueous suspension of a young culture. In such preparations there is seen within the rods a number of individual elements, apparently, each of which is supplied with flagella. These structures become independent and separate from the rod proper (fig. 5; Pl. VII, E, F, G, H). In the cultures are found also, especially in the condensation water of brood-filtrate-agar slant cultures (Pl. VIII, D), giant whips (fig. 6; Pl. VII, F, G, H) of various sizes. That the little-understood changes that take place in the vegetative forms bear a close relation to the formation of the giant whips can readily be suspected.

Definite data have been sought to prove the identity of the rosy foulbrood of the different countries. Samples of brood comb containing disease material were received from Canada, Cuba, England, France, Germany, New Zealand, and Switzerland. The findings from studies made on these were compared each with the other and with the findings from many samples from the United States. Spores of *Bacillus larvae* in very large numbers and practically in pure cultures were present in every one. In each instance one of the special media (p. 18, 19) required for the cultivation of this species was needed. Culturally the bacillus was the same from all of the samples. The disease produced by the inoculation of colonies of bees was also similar in every instance. Sera from rabbits immunized with cultures from American sources agglutinated in high dilutions cultures from English, New Zealand, and Switzerland sources at least, these being all that were tested in this way. The evidence, therefore, justifies the conclusion that the rosy foulbrood of each of the different countries mentioned above is identically the same disease.

Four rabbits inoculated with pure cultures of *Bacillus larvae* showed comparatively little reaction. In each instance there was used a moderately clouded suspension in normal salt solution made from the surface of the brood-filtrate-agar slant culture about 24 hours old. Two of them were inoculated subcutaneously with 1 and 2 c. c. of the suspension, respectively; one received the culture intraperi-

usually spreads more or less rapidly within an infected colony, the fact remains that it frequently does not.

It was observed that many diseased colonies could be present in the experimental apiary without causing the infection to be transmitted to other colonies in the apiary. This fact is naturally very significant. On account of it certain views concerning the manner of transmission of the disease, which might otherwise be regarded as probable, are rendered untenable. If flowers visited by bees from infected colonies, and later by bees from healthy ones, are a likely source of infection, or if the water supply is such a source, or if drones are a means by which the disease is likely to be transmitted, there would have been a different observation to report.

In a few instances in the experimental apiary colonies near heavily infected ones became infected. That the disease may have been transmitted through the drifting or accidental straying of bees is one of the possible explanations for the disease in these cases. That a slow form of robbing might have taken place should be considered also as a possible explanation in these cases.

Brood comb containing brood dead of American foulbrood will transmit the disease when placed in a hive containing a healthy colony. The likelihood that the disease will be transmitted by combs from diseased colonies, which contain honey but no brood, probably is frequently overestimated. It would seem that a spread of the disease in this way would depend considerably upon the amount of infection that was present in the colony from which the combs were removed. This would depend also somewhat upon the presence or absence of brood in the colony to which the combs were given. Sufficient facts are wanting to make definite statements in regard to the probability of infection in such cases. Robbing material containing the spores of American foulbrood from any source is likely to transmit the disease although it does not necessarily do so.

How often the disease would be transmitted through the medium of hives which have housed infected colonies, if used without flaming, has not been definitely determined. Experimental colonies have been placed in such hives and kept in them for a year with the result that no disease appeared.¹ It probably will be found that in many cases the treatment of the hive bodies is not necessary to insure that the disease will not be transmitted by them. From the results obtained by practical apiarists and by observation made in the experimental apiary during these studies the fact has been well established,

¹ An experiment in which four colonies were used, was made as follows: The insides of the top and bottom board of each of two hive bodies were washed with an aqueous suspension of spore-containing material and allowed to dry, and the inside of the walls of each of two others were similarly washed and allowed to dry. Colonies were transferred to these four hives during the summer. American foulbrood appeared in the two colonies housed in hives of which the tops and bottoms had been contaminated with disease material but did not appear in the other two. These results, naturally, are not conclusive but they are suggestive.

however, that the danger of infection from such hives is entirely removed by carefully flaming them inside. The destruction of the hive is, therefore, never necessary. Chemical disinfectants should not be relied upon for the destruction of the spores of American foulbrood as the spores possess a marked resistance to these agents. If any chemical is used, however, strong solutions of formaldehyde would seem to offer some promise of being efficient.

After disease material is removed from the hive by bees and is released from them the chances that a bee will come in contact with the contained spores again is comparatively slight. Furthermore such spores must withstand certain agencies in nature which tend to destroy them, thus decreasing the chances still further that disease will result from them. If exposed to the direct rays of the sun the spores will be destroyed more or less readily (p. 29). Much less is to be expected from fermentation (p. 31) or drying (p. 29). Should the spores reach the soil or running water the likelihood that bees will come in contact with them and carry them to the feeding brood is indeed slight. Should the spores reach the water supply of the bees and should this supply be a stagnant or slow-moving body of water, the chances naturally would be somewhat increased.

Experiments in which queens taken from diseased colonies were introduced into healthy ones were not kept under observation for a sufficiently long period to justify a definite conclusion as to the probability of the disease being transmitted by such queens, but the data secured indicate strongly that the danger of transmission in this way has been overestimated at times. The favorable results obtained by beekeepers using the shaking treatment should tend to allay fear in regard to the transmission of the disease by this route. Indeed the facts thus far obtained suggest that the transmission of the disease by way of the queen should not be expected.

The spread of the disease by means of the clothing or hands of the apiarist is not to be feared especially. The hive tool, if brought in direct contact with dead larvæ in testing for the presence of disease, might serve to transmit infection, but during the usual manipulations it would not. The practice sometimes followed by beekeepers of thrusting the hive tool into the soil to clean it would seem to be a safe procedure. Washing the hands with water instead of disinfectants is more convenient and is sufficient. Reasonable care should be taken, of course, that the water used does not become or reach the water supply of bees.

DIAGNOSIS

American foulbrood is the easiest of the brood diseases to diagnose. Methods by which this can be done in the laboratory are given in an earlier publication (16). The diagnosis as a rule can be

made from the symptoms (p. 5) alone. No helpful sign is found in the appearance of the adult bees. A weak colony justifies a suspicion that a disease is present. In American foulbrood, as in European foulbrood and sacbrood, a sample suitable for diagnosis must contain the remains of brood dead of the disease.

The colony symptoms which are usually adequate for a definite diagnosis of American foulbrood are the following: The death of larvæ in capped cells after the endwise position has been assumed (Pls. I, II, III, VI), and the death of pupæ soon after transformation (Pls. IV, V, VI), the brown shade of dead brood, the viscosity (ropiness) of the decaying remains, the character of the scales, and the foulbrood odor.

BACTERIOLOGICAL EXAMINATION

A conclusive diagnosis of American foulbrood can always be made from a bacteriological examination of brood dead of the disease. With gross characters suggesting the disease the experienced can frequently make the tentative diagnosis definite by a water mount made from the decaying brood remains, or the scales. A very large number of spores free from rods with no other bacterial species present is the characteristic microscopic picture in the disease. The spores are those of *Bacillus larvae* (fig. 4; Pl. VII, B, D). As a rule, a stained preparation does not furnish much additional aid. In all cases of doubt cultures (agar plates are satisfactory) should be made. The absence of growth on the plates when the other data strongly suggest American foulbrood is sufficient for a positive diagnosis. In routine work the cultures should always be made. Occasionally further evidence that the spores present are those of *B. larvae* is desired. This can be obtained by the employment of methods and media given in this paper (p. 17).

DIFFERENTIAL DIAGNOSIS

EUROPEAN FOULBROOD

European foulbrood can be recognized (27) in most instances by the death of brood in uncapped cells, the yellow hue of larvæ recently dead changing later often to a brown, and an absence of the foulbrood odor. In cases in which these younger larvæ have been removed, the diagnosis of European foulbrood can very often be made from the remains of brood which has died in capped cells. In these cases the remains of dead larvæ and not of pupæ are encountered. These decaying masses pass through a stage at which they are somewhat viscid. The scales are rubberlike¹ in consistency. In these masses and in the scales large numbers of *B. alvei* are found.

¹ The term "rubberlike" needs interpretation. When applied to the scales of European foulbrood it means simply that they are less brittle than either those of American foulbrood or sacbrood. The property "elasticity" as usually thought of in common parlance in connection with rubber is not meant.

SACBROOD

Sacbrood is recognized (25) by the death of larvæ in capped cells and not of pupæ, by the saclike appearance of the dead remains, and by the absence of viscosity. The absence of microorganisms in the remains characterizes the microscopic picture.

OTHER CONDITIONS

Other brood conditions referred to as chilled brood, overheated brood, starved brood, and in some cases drone brood, must be differentiated from American foulbrood. The history of the case, the age of the brood at the time of death, and the absence of ropiness and of the foulbrood odor, usually make the diagnosis comparatively easy.

In some of the disorders of adult bees excrement of the adult bees is sometimes found in the cells of the brood combs. When dry the masses resemble somewhat brood-disease scales. The character of the masses together with the microscopic picture is usually sufficient for a diagnosis. In these cases a stained preparation is preferable. The fecal matter contains bacterial rods in large numbers. In all of these conditions the absence of *B. larvae* furnishes definite evidence that American foulbrood is not present.

PROGNOSIS

Without treatment the prognosis in American foulbrood is decidedly grave, the rule being that the colony sooner or later dies as a result of the disease. This is true for experimental colonies and is true also, as has been proved by the experiences of beekeepers, for colonies in which the disease has occurred through natural means.

A colony heavily inoculated experimentally is not destroyed by disease in one month or two months. Loss in strength may be apparent, however, after one month. If a colony is inoculated early in the season and is heavily infected, it may die by midsummer; if less heavily infected, it may live longer but die later in the season. The infection may be so slight, indeed, that the colony may not be destroyed directly but be so weakened that it will die during the winter or surviving emerge a weakened colony in the spring and then die of the disease during the following bee season. When a colony during the summer contains much dead brood and becomes very weak as a result of the disease, it usually absconds. The queen is to be found among the bees to the last, and stores are not wanting as a rule.

A question of considerable interest but one which has not yet been completely answered is: Does an American foulbrood colony ever recover without treatment? Some beekeepers have entertained the

belief that occasionally it does. Experimental evidence indicates that it probably does. Colonies in the experimental apiary, with a larva or pupa dead of the disease here and there only, certainly did not become badly diseased for more than a year and apparently recovered. To have proved conclusively, however, that such colonies were completely free from possible infection from within would have necessitated observations over a much longer period.

It is known that worker, drone, and queen larvæ die of the disease. Theoretically it is possible that a colony might become queenless as a direct result of American foulbrood but care must be taken in attributing this condition to the disease, for very often queens are reared in diseased colonies, and to all appearances are healthy. Whether a larva once infected ever recovers from the disease is not known.

From the facts at hand it may be concluded, therefore, that the prognosis in American foulbrood in an untreated colony is especially grave. From the practical viewpoint, at least, complete recovery from the disease without treatment, if it occur at all, should be considered for the present to be the exception. While an infected colony may live for a long time and yield a profitable surplus for a considerable period, this is not the rule; more often the course of the disease is comparatively short, and the destruction of the colony the outcome.

SUMMARY AND CONCLUSIONS

A brief summary of facts known about American foulbrood together with a few conclusions drawn from them are given here. Some of the facts have been known for many years, others are of more recent origin, and still others are new. All of them are supported by experimental studies recorded in the present paper.

1. American foulbrood is an infectious disease of the brood of bees caused by *Bacillus larvae*.

2. All larvæ—worker, drone, and queen—are susceptible to the infection; adult bees are not.

3. Man evidently is not susceptible to infection with the organism nor are the experimental animals.

4. So far the disease has not been encountered or produced in other insects than honeybees.

5. The brood of bees can be infected through feeding the spores of the bacillus to a colony.

6. The spores contained in a single scale are more than enough to produce considerable disease in the colony.

7. The portal of entry of the infecting agent is somewhere along the alimentary tract of the larva, most likely the stomach (mid-intestine).

8. Practically speaking there are no secondary invaders either during the life of the infected larva or during the decay of the remains.

9. The incubation period is approximately 7 days.

10. The brood is susceptible to infection at all seasons of the year.

11. More brood dies of the disease during the second half of the brood-rearing season than during the first half.

12. The disease is present at least in Australia, New Zealand, Denmark, England, Ireland, Germany, France, Switzerland, Canada, Cuba, and the United States. The rosy foulbrood of all these countries is one and the same disease.

13. Occurring as it does in such a wide range of climatic conditions, it is evident that the presence of the disease can not be attributed alone to any particular climate.

14. The course of the disease in the colony is not affected greatly, if at all, by the quality of food used by the bees, or by the quantity present.

15. Colonies in which the disease has been produced through artificial inoculation can be kept in the experimental apiary without transmitting the disease to others. This fact is of special importance not only in the technique of making studies, but also in the control of the malady.

16. The spores of American foulbrood remain alive and virulent for years in the dry remains (scales) of larvæ and pupæ dead of the disease and in cultures that have become and remain dry.

17. The spores are very resistant to most destructive agencies. A variation in resistance is noted both as to the individual spores of a sample and as to the spores contained in different samples.

18. Many of the spores are killed within 1 minute at 100° C. and all of them from some samples are killed in less than 5 minutes. In some instances 96° C. maintained for 10 minutes will destroy all of the spores while 98° C. will often do it. The most resistant of the spores studied when suspended in water have not withstood 100° C. for 11 minutes.

19. The spores withstand more heating when they are suspended in honey or honey diluted with water than when suspended in water.

20. The spores suspended in honey or diluted honey can be destroyed by 100° C. but it may require half an hour or more to do so.

21. American foulbrood spores when dry were destroyed by the direct rays of the sun in from 28 to 41 hours.

22. The spores when suspended in honey and exposed to the direct rays of the sun were destroyed in from 4 to 6 weeks.

23. The spores when suspended in honey and shielded from direct sunlight remained alive and virulent for more than a year. It

is very likely that they are capable of remaining so for a very much longer period.

24. The spores resisted the destructive effects of fermentation for more than 7 weeks at incubator and outdoor temperatures, respectively, and probably are able to withstand these agencies for a very much longer period.

25. The spores resist carbolic acid at room temperature in strengths ordinarily used as a disinfectant for periods of months; 1 to 1000 mercuric chlorid for days; 10 per cent formalin for hours.

26. Experiments recorded in the present paper indicate that drugs do not materially affect the course of the disease.

27. American foulbrood infection is transmitted primarily through the food of bees; possibly at times to some extent through their water supply. Robbing from the diseased colonies of the apiary, or from neighboring apiaries, is the most likely mode by which the disease is transmitted in nature.

28. The placing of brood combs containing diseased brood with healthy colonies will result in the transmission of the disease.

29. Flowers should not be considered as a likely medium through which infection may take place.

30. Whether the disease is ever transmitted by queens or drones has not been determined. That they have been overestimated at times as possible sources of infection seems likely.

31. It is quite probable that in many cases hives which have housed colonies infected with American foulbrood will not transmit the disease to healthy colonies transferred to them. Results from the present studies confirm the observation made by beekeepers that danger from this source may be removed by properly flaming such hives inside.

32. The clothing of those about an apiary, and the hands of the apiarist are not fruitful sources for the transmission of the disease.

33. Tools and bee supplies generally about an infected apiary will not transmit the infection in the absence of robbing from those sources.

34. American foulbrood usually can be diagnosed from the symptoms alone. A definite diagnosis can always be made from suitable samples by bacteriological methods.

35. The prognosis in the disease in the absence of treatment is decidedly grave but with proper treatment it is favorable.

36. From the technical viewpoint many of the problems considered in these studies have been solved only partially; from the practical point of view, however, the results are sufficient to make a logical, efficient, and economic treatment of American foulbrood possible.

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EXPLANATION OF PLATES

PLATE I

Brood affected with American foulbrood:

A.—American foulbrood produced by the feeding of pure cultures of *Bacillus larvae*, showing the later stages of decay of the brood.

B.—American foulbrood produced experimentally, showing irregular distribution of capped and uncapped cells, punctured caps, and scales.

C.—American foulbrood, showing sunken and punctured caps. The sample was shipped by mail for diagnosis.

PLATE II

Healthy bee larvæ (prepupæ) and first and second postmortem stages of American foulbrood larvæ as described in the present paper:

A.—Cap of cell containing a healthy larva. Being recently constructed, it is convex.

B.—Cap of cell containing a larva recently dead of the disease. It is not unlike many of the caps over healthy larvæ.

C.—Cap of cell containing a diseased larva. It is slightly sunken.

D.—End view of a healthy larva. The cap was removed artificially. (In the laboratory this is done conveniently with fine pointed curved forceps or a dissecting needle.)

E.—End view of larva illustrating the earliest (first) stage of American foulbrood.

F.—End view of larva which has reached the second stage.

G.—Ventral view of a healthy larva of the age at which death from American foulbrood frequently occurs.

H.—Ventral view of larva illustrating the first stage after death.

I.—Ventral view of larva showing second stage.

PLATE III

Third, fourth, and fifth stages of decay in American foulbrood larvæ:

A.—Punctured cap of cell containing a dead larva.

B.—End view of larva illustrating the fourth stage of decay. The cap was removed artificially as indicated by the torn edges.

C.—End view of larva illustrating the fifth stage of decay, the scale. The cap had been removed by the bees, as shown by the smooth condition of the mouth of the cell.

D.—End view of larva, third stage.

E.—End view of larva, fourth stage.

F.—End view of larva, fifth stage—the scale.

G.—Ventral view of larva, third stage.

H.—Ventral view of larva, fourth stage.

I.—Ventral view of larva, fifth stage—the scale.

PLATE IV

Healthy pupæ and first and second postmortem stages of American foulbrood pupæ as described in the present paper:

A.—Healthy pupa of the age at which death from American foulbrood occurs.

B.—End view of pupa, first stage of the disease.

C.—End view of pupa, second stage.

D.—Ventral view of pupa of the age at which death from American foulbrood occurs.

E.—Ventral view of pupa, first stage.

F.—Ventral view of pupa, second stage.

PLATE V

Third, fourth, and fifth postmortem stages of American foulbrood as described in the present paper:

A.—End view of pupa, third stage.

B.—End view of pupa, fourth stage.

C.—End view of pupa, fifth stage—the scale.

D.—Ventral view of pupa, third stage.

E.—Ventral view of pupa, fourth stage.

F.—Ventral view of pupa, fifth stage—the scale.

PLATE VI

Various phases of the appearance of brood dead of American foulbrood:

- A.—Larva in cell not yet capped, dead of American foulbrood.
- B.—A developing bee dead of American foulbrood immediately before entering the pupal stage.
- C.—A punctured cap with two holes.
- D.—Larva dead of American foulbrood gnawed and partially removed by the adult bees.
- E.—End view of larval scale. The cap was removed artificially.
- F.—End view of pupal scale.
- G.—Lateral view of healthy larva in capped cell.
- H.—Lateral view of larval scale in the cell cut lengthwise. The cap had been removed by the adult bees.
- I.—Lateral view of pupal scale in position in cell cut lengthwise.

PLATE VII

Vegetative form, spore formation, spores, flagella, and giant whips of *Bacillus larvae*. Photomicrographs:

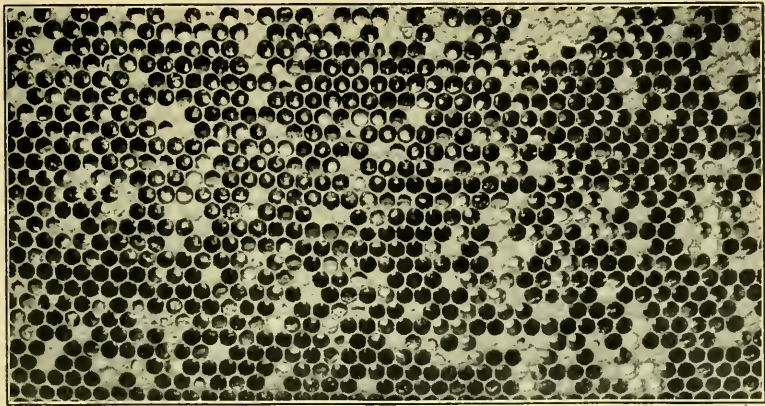
- A.—Vegetative form from a 24-hour culture on the surface of brood-filtrate agar. $\times 1000$.
- B.—Spore formation and spores from the surface of brood-filtrate agar. $\times 800$.
- C.—Flagella. Stained by Loeffler's method as modified by Johnson and Mack. $\times 1000$. (Retouched.)
- D.—Spores from a stained smear made directly from a decaying larva dead of American foulbrood. $\times 1000$.
- E.—The production within the rods of separate elements, each being supplied with flagella. $\times 1000$.
- F.—Giant whips and small spherical bodies in the older cultures of *B. larvae* obtained from the water of condensation of a brood-filtrate-agar slant culture. Fixed in 50 per cent formalin and stained with carbolfuchsin. $\times 1000$.
- G.—Small and larger giant whips, and spherical bodies similar to those of F. $\times 1000$.
- A similarity existing between the microscopic appearance of giant whips and spirochetes caused Maassen (14) to believe them to be spirochetes and to introduce the name *Spirochaeta apis*.
- H.—Very large whip, and spherical bodies similar to those of F and G. $\times 1000$.

PLATE VIII

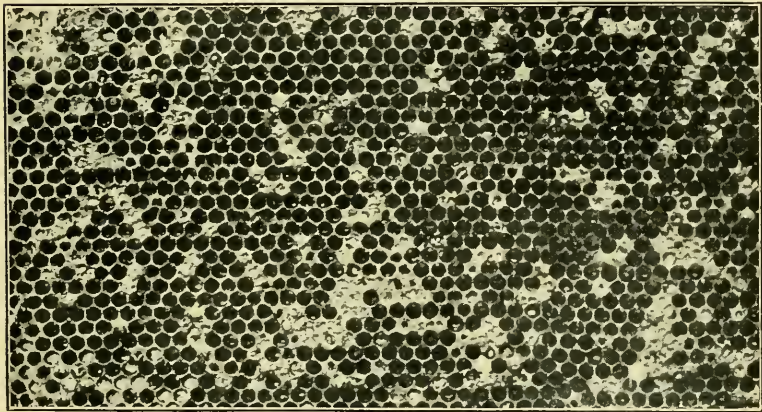
Colonies and cultures of *Bacillus larvae*:

- A.—Surface colony and deep colonies as seen in brood-filtrate agar plates.
- B.—Surface colony on brood-filtrate agar more highly magnified.
- C.—Deep colony in the same medium, magnified.
- D.—Surface growth on brood-filtrate-agar slant.
- E.—Culture of *Bacillus larvae* in bee-larvæ agar when the Liborius method is used. The growth is throughout the upper third of the medium.
- F.—The culture is similar to E but the growth is nearer the surface.
- G.—The culture is restricted in the agar and is near to but not at the surface of the medium.
- H.—The growth is less restricted in area and farther from the surface than in G.
- I.—The growth is very restricted in area and is below the middle of the medium.

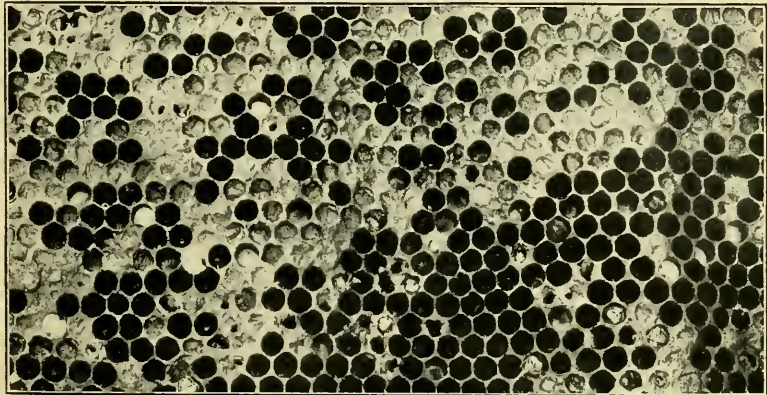




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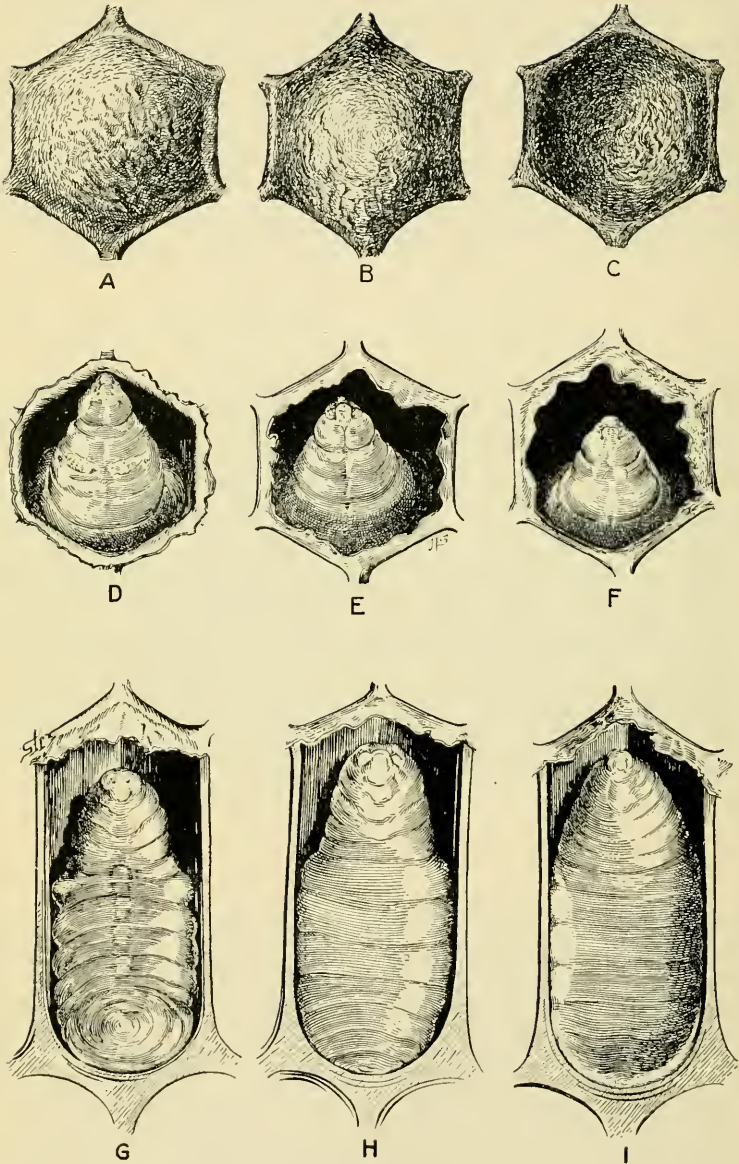


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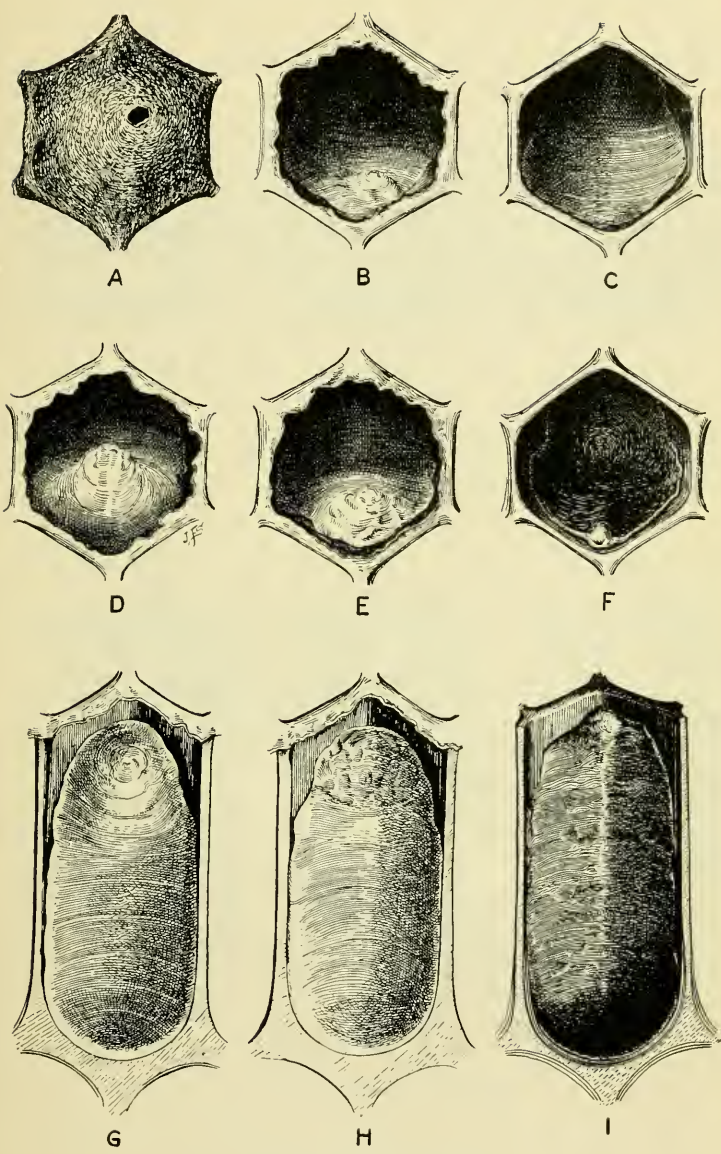


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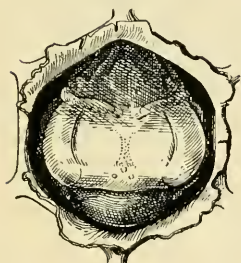
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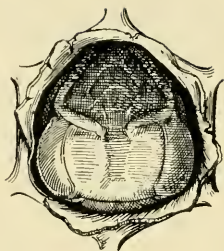
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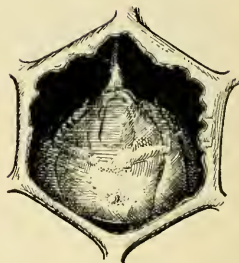
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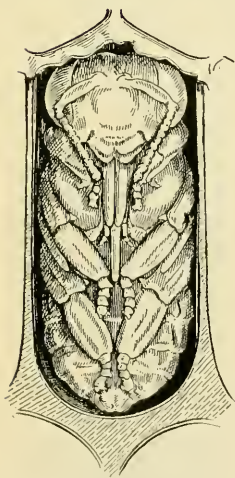
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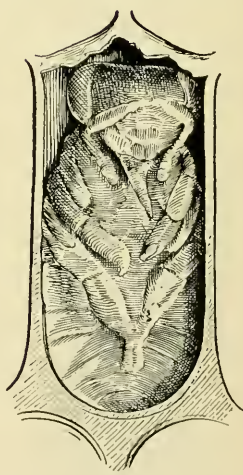
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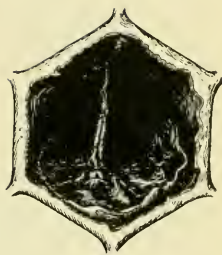
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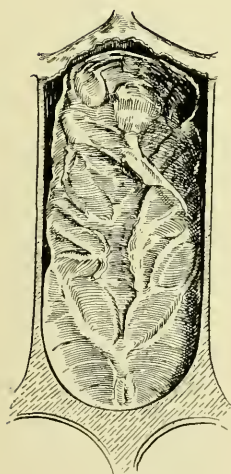
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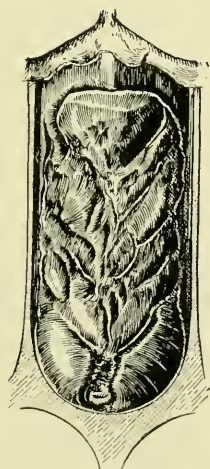
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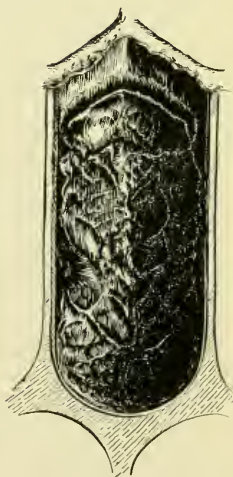
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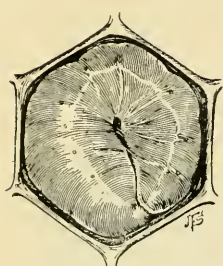


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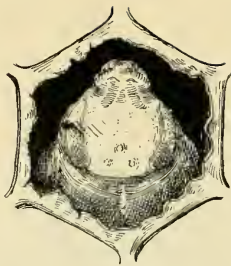


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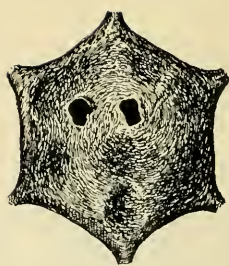
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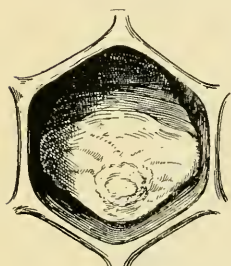
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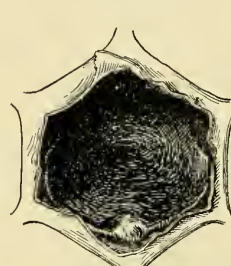
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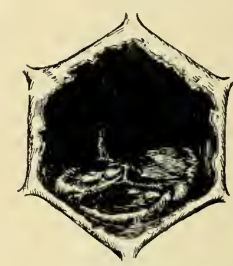
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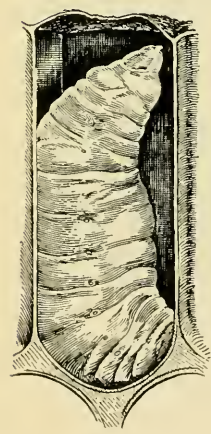
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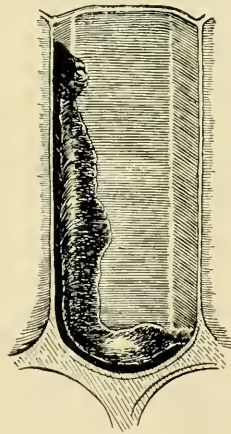
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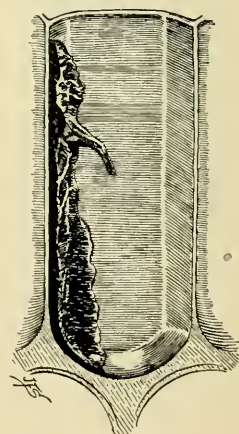
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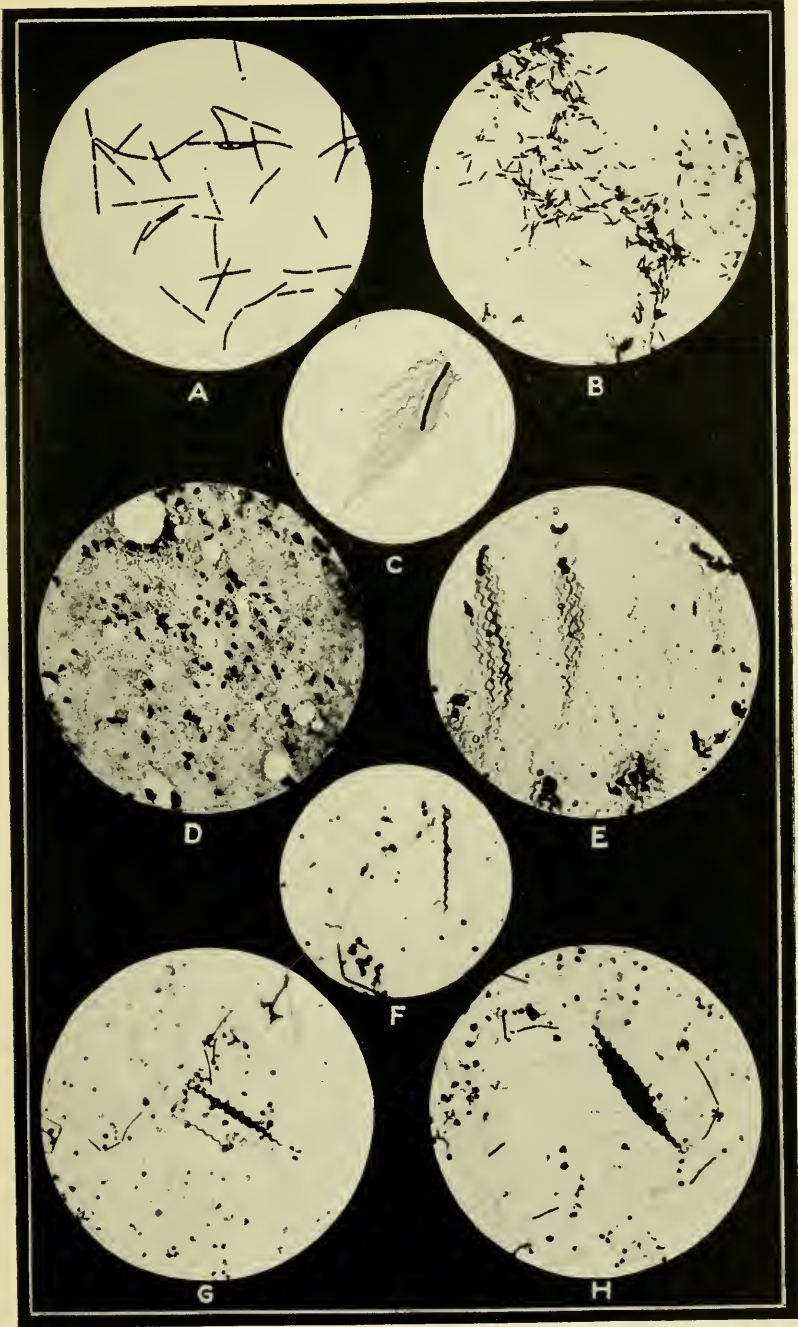


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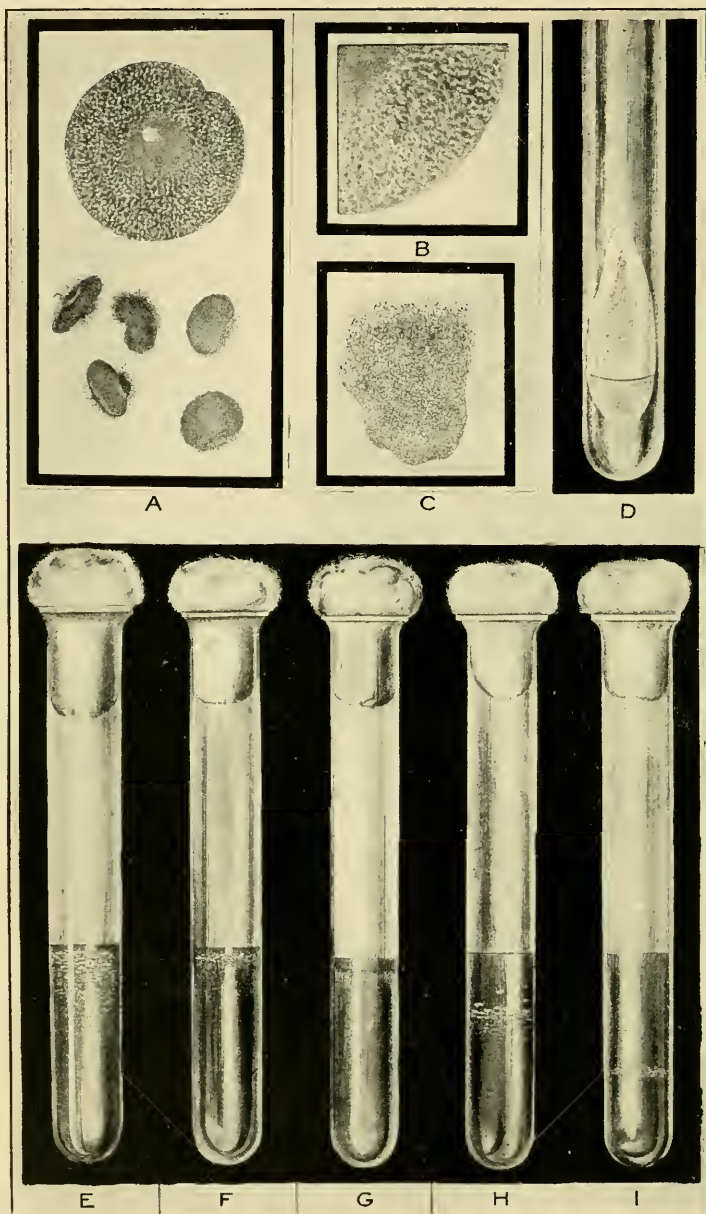


I

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toneally and one intravenously. The temperature taken of the latter two throughout the day of the inoculation was found to be increased about 3° F. following the inoculation. The next day they were somewhat sluggish with impaired appetite. The temperature, however, soon declined to normal and their feeding became normal. The 1,500 gram rabbits were from 100 to 200 grams light in weight on the day after the inoculation but soon the loss was regained. Observations were made over a period of 2 months. Autopsies on the chloroformed animals showed no abnormalities worthy of note.

Four guinea pigs inoculated subcutaneously with cultures similar to those used in the rabbit inoculations showed only slight reaction. The temperature of the one taken throughout the day of inoculation showed a rise of about 2° F. but was normal thereafter. No loss in the weight of these 400 to 500 gram guinea pigs was appreciable. One died in 10 days, apparently from causes foreign to the inoculation. The remaining three were chloroformed after 6 weeks and presented no abnormalities of note at autopsy.

Two gray rats were inoculated subcutaneously, one with the vegetative and the other with the spore form of *Bacillus larvae*. These proved to be refractory. After 4 weeks they were chloroformed and at autopsy no abnormality of interest was noted except a slight infiltration at the point of inoculation in the animal receiving the vegetative culture, and a small abscess in the case of the animal receiving the spore suspension. In the abscess spores were present.

TECHNIQUE

Much of the time devoted to the study of American foulbrood has been consumed in the study of technique. Special media were required and the method of conducting the experimental studies had to be developed.

MEDIA

Failure to recognize the fact that the spores occurring in such large numbers in the brood dead of American foulbrood do not grow on the media ordinarily used in the laboratory has caused a number of workers to go astray and has contributed not a little to the confusion that has existed concerning the brood diseases. Lambotte (13) in Belgium experienced some difficulty in obtaining cultures following inoculations with the spore-bearing disease material. He made a medium using the brood of bees in its preparation and with it obtained a growth which he interpreted as being the species represented by the numerous spores present in the brood dead of the disease. The interpretation was evidently incorrect. The culture which he obtained he identified as a member of the *mesentericus* group. In 1903, before learning of Lambotte's work, the writer (20) had made an agar using bee larvae and obtained a germination of the spores of the

ropy foulbrood. In this bee-larvæ agar¹ the growth is always slow and somewhat feeble. Spores are produced to a slight extent only or not at all. Such cultures are unsuitable for experimental purposes.

A medium containing a sterile filtrate obtained from the brood of bees was devised by the writer (23) which meets the requirements of experimental studies. It is prepared as follows: Healthy larvæ taken from the brood comb are crushed and the crushed mass is diluted with water to several times its volume. This is placed in a flask, and after adding a few c.c. of chloroform the flask is stoppered and allowed to remain at incubator temperature overnight. The suspension then can be

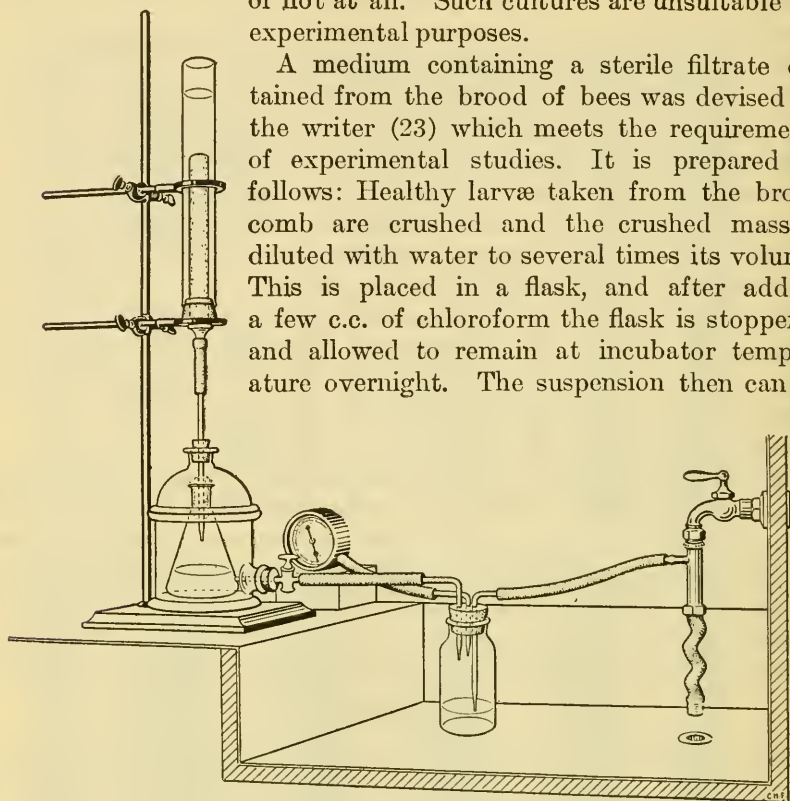


FIG. 7.—A convenient method for obtaining sterile filtrates.

filtered easily by using any bacteria-proof filter² (fig. 7). The filtrate is pipetted aseptically into sterile tubes and stored until

¹ Larvæ, prepupæ, or pupæ recently transformed furnish satisfactory brood material for making the bee-larvæ media. These are picked from the brood combs, crushed, and used as meat in formulas ordinarily followed in making bouillon and agar. Excess heating should be avoided. In making the inoculations an aqueous suspension of the spore-containing material heated to 100° C. for one or two minutes should be used. A tube of the special agar liquefied is inoculated with a loopful of the heated suspension. After cooling it is incubated at about 38° C. Three days or more may be required to produce a visible growth (Pl. VIII, E, F, G, H, I).

² In caring for and using the filter cylinders in these studies the following course has been pursued: The cylinder is immersed in water for a few hours or over night and is then sterilized in the autoclave. After being used for filtering a brood suspension it is washed in water without scrubbing. To remove further the brood material water is drawn through the cylinder under pressure as in filtering. As a rule it is again immersed in water and allowed to remain over night, after which, the filter being assembled, water is filtered again. It is then ready for use and may be stored until needed. Cylinders which have been used repeatedly in this way have lost none of their efficiency. The vacuum chamber is made in two sections similar to a Novy jar. Vaseline is used on the wide ground flanges. No rubber band or clamps are needed.

The flasks used in the vacuum chamber of the apparatus before being sterilized are stoppered with cotton wrapped about a small-sized test tube. The cylinder having been immersed in water is sterilized together with the rubber connections and glass tubing in place, but without the glass mantle. In assembling the apparatus sterilized connection between the cylinder and flask in the vacuum chamber is readily obtained through the opening in the plug left by removing the test tube. After a vacuum has been established in the chamber the stopcock may be closed and the pump turned off.

needed. About 1 c.c. of the brood filtrate is added to each 5 c.c. of agar liquefied and cooled to about 50° C. After being inclined the medium is ready for use and may be stored. Plating for pure cultures may be done by adding the brood filtrate to the agar at the time the plates are made.¹

When it is desired to obtain cultures from the spore form of *Bacillus larvae*, brood-filtrate agar is not a suitable medium in itself. The spores should be germinated first by inoculating bee-larvæ agar (p. 18) or egg-yolk-suspension agar. By plating in 2 or 3 days the vegetative form thus obtained, using brood-filtrate agar, pure cultures can be assured. Studies have shown, however, that *Bacillus larvae* is present in practically pure cultures in brood dead of the disease, and by heating the spore-containing material in aqueous suspension at 100° C. for one or two minutes as suggested above the occasional contaminating organisms are eliminated usually without plating.

Bee-larvæ agar is limited in its usefulness on account of the large amount of brood required in its preparation. A more suitable medium, therefore, was sought. An unheated egg-yolk agar was found by the writer (28) to be very satisfactory. This is prepared as follows: Fresh eggs are used. After having been immersed in a disinfecting solution the shell is broken, the white of the egg is poured off, and the yolk is dropped into a flask containing about 70 c.c. of sterile water. With a sterile pipette the aqueous suspension of yolk, resulting from agitating the flask, is transferred to sterile tubes and stored until needed. In making an egg-yolk-suspension agar about 1 c.c. of the egg-yolk suspension is added to each 5 c.c. of agar in tubes liquefied and cooled to about 50° C. The agar is inclined and may be stored until needed.²

¹ Larvæ, prepupæ, or young pupæ may be used in obtaining the brood filtrate. The use of sterile water is a good precaution in making the dilution of the crushed brood mass. A dilution of 1 to 10 up to 1 to 50 gives very satisfactory results, although lower and higher dilutions have been used with success, while at incubator temperature an autodigestion apparently takes place. The "autodigested" suspension is passed through filter paper before the bacteria-proof filter is used. For the latter the Pasteur-Chamberland F is very satisfactory. (Fig. 7.) The B grade has been used but the filtering is slower. The Berkefeld N has also been employed, but is less efficient. In using this latter type of filter gravity alone should be employed. If the weather is warm, or if the filtering is not to be done for a few days, the aqueous suspension may be allowed to remain at room temperature. This permits the changes which take place to advance sufficiently to make the filtering process comparatively easy. The chloroform saturated suspension of brood material has been kept at room temperature for more than three years without its usefulness being impaired to any appreciable extent. After a considerable period the suspension becomes practically sterile and has been used without being filtered. When an early use of the filtrate is desired its sterility should be tested by placing the tubes containing it at incubator temperature for a few days. Sometimes it is desirable to use other brood-filtrate media than the agar. In this event a small amount of brood-filtrate may be added to any one of the media ordinarily used in the laboratory. Such special media usually support a growth of *Bacillus larvae* when inoculated with the vegetative form of the organism.

² Eggs obtained from the market labeled "strictly fresh" have been suitable as a rule for the egg-yolk suspension. Eggs known to have been recently produced are to be preferred, however. Almost any of the more common efficient disinfecting solutions may be employed for sterilizing the eggshell. Aqueous solution of mercuric chlorid 1:1000; carbolic acid 5 per cent; formalin 10 per cent; and alcohol each have been used, mercuric chlorid being preferred. To insure sterility autoclaving of the flasks with the contained water has been practiced. A wide-mouthed flask is preferred. In securing the yolk aseptically, it

EXPERIMENTAL INOCULATIONS

A very satisfactory colony for inoculation purposes is a queen-right nucleus that can be accommodated comfortably on from 3 to 5 brood frames approximating the Langstroth size. The hive, the arrangement of the apiary, the colony, the feeding, and the manipulations in general are similar in the experimental study of American foulbrood to those employed by the writer in the study of sacbrood (25), Nosema-disease (26), and European foulbrood (27). The inoculated colonies were, therefore, in the open. Precautions tending to minimize the likelihood of robbing, swarming, absconding, and the accidental straying or drifting of bees should not be overlooked.

The inoculations are made by feeding a suspension of the spores of *Bacillus larvae* in sirup or honey, the spores being obtained from pure cultures or from brood dead of American foulbrood. Three or four tubes of spore-containing cultures grown on brood-filtrate or egg-yolk-suspension agar furnish a suitable quantity of the virus. Likewise the spores contained in three or four scales give satisfactory results. In some experiments, feedings made on successive days are desirable. Direct inoculation by means of a capillary pipette is less satisfactory in experiments on American foulbrood than in those on sacbrood.¹

The first symptoms of American foulbrood to be observed following the inoculation usually appear in the worker larvæ by the end of the first week and not earlier than the sixth day. The affected larvæ are in capped cells. Not infrequently the first evidence of disease noticed is the remains in cells here and there of partially removed

is convenient to break the sterilized shell about one end of the egg, remove the pieces with flamed forceps, and, after making a small hole in the other end, pour off the white. The yolk remaining is poured into the flask. By breaking the limiting membrane of the yolk at the time of pouring into the flask the process is facilitated. Different degrees of dilution of the egg yolk have been employed, 60 c.c. to 80 c.c. of water giving satisfactory results. Any ingredient, such as the sugars, desired in the final medium may be added to the water of the flasks. The egg of the hen has been used in most of the studies reported here. Eggs of the duck were also found to be suitable. Occasionally a contamination of the egg suspension will be found. In these cases the suspension becomes firm after incubation resembling then the consistency of coagulated milk cultures. If the contamination is present it will be apparent in a few days after storing, or it may be determined earlier at incubator temperature. The sterile egg-yolk suspension as an ingredient for special media retains its efficiency for a long period. Indeed an aqueous suspension of the dry residue from the yolk suspension was found to be efficient after 3 years, although its value is then apparently somewhat impaired.

Maassen (15) used bee-larvæ and also brain agar in studying *Bacillus larvae*. The egg-yolk suspension agar, in the writer's experience, has advantages over the brain agar.

¹Cultures on the surface of agar are readily suspended in water as is also the disease material in the decaying larvæ and scales of American foulbrood. These aqueous suspensions are used in making the sirup or honey suspensions. From 1 to 3 c.c. of water for each scale is a convenient proportion. Sirup is made by bringing to the boiling point an aqueous suspension of granulated sugar in which the sugar used exceeds that of the water. When honey is used for the spore suspension it is diluted with water, the amount of water added being slightly less than that of honey. In most instances honey is less suitable than sirup inasmuch as it tends to encourage robbing especially during a dearth of nectar, it needs to be sterilized before use, and is more expensive. It was found that less than one scale is sufficient disease material to produce a considerable amount of disease in the colony. In some experiments one scale, therefore, might supply all of the spores needed although the use of a somewhat greater quantity of material is advisable in most instances.

larvæ (Pl. VI, D), about one-third of the larva being removed. The transparency seen in healthy larvæ disappears, and the bodies of the ones affected become more nearly opaque. Soon the color assumes a tint of brown which deepens as the process of decay continues, passing through chocolate, coffee, and mahogany shades. In the earliest stages of the disease the body wall is ruptured more easily and the tissues are softer than in healthy brood. As the disease advances a ropiness of the decaying brood is to be observed, the characteristic odor appears, and a loss in the strength of the colony is evident. After a time an irregularity in the appearance of the brood comb is to be seen, the capped and uncapped brood being abnormally distributed with here and there perforated and sometimes sunken caps (Pl. II, A, B, C). Still later the scales are found.

The time at which the various symptoms appear varies. Climatic conditions, the amount of infection present, and the initial strength of the colony are some of the more important factors causing the variations.

Whether a hive which has housed a colony infected with American foulbrood will transmit the disease is a question which has not been altogether solved but in experimental work all hives that have housed such colonies should be disinfected before they are used again. This can be done satisfactorily by flaming the inside of the hive. If gas is available the Bunsen burner is very satisfactory for this purpose. That no fear need be entertained from hives which have been flamed properly is demonstrated by the fact that the disease has not been transmitted by flamed hives in the experiments made in the present studies, although the number of such hives which have been used is large. The length of time that a sirup or honey suspension of American foulbrood spores stands before the inoculation of a colony is made need not be considered in experimental work.

From what is known of American foulbrood its transmission by queens is not to be expected. Two queens from diseased colonies were introduced into healthy ones in October and the colonies were kept under observation until the following July. The disease did not appear in either of them. In a number of instances during the investigations queens from American foulbrood colonies were used to queen nuclei made by division of healthy colonies. These colonies were under observation for weeks or months before they were used for American foulbrood experiments. In no instance was the disease observed to result from the use of these queens. The conclusion is reached, therefore, that for most experimental work at least the possible previous relation of the queen to diseased colonies need not concern one.

The combs from an American foulbrood colony never should be given to a colony which is to be used for experimental purposes.

The bees from diseased colonies may be used again in certain well-selected cases by transferring them to another hive which may be supplied with comb from healthy colonies or with foundation strips or full sheets. To insure that no infection is present a colony treated in this way should be under observation for a considerable period after brood rearing has begun in it before it is used again.

Further reference to the technique used in these studies will be made as the experiments are recorded.

THERMAL DEATH POINT OF AMERICAN FOULBROOD SPORES

In an earlier paper (24) the results from preliminary experiments were given which indicate the amount of heating that is necessary to destroy the spores of American foulbrood when they are suspended in water. The importance of heat as a means for the destruction of these spores in practical apiculture is so great that a further development of the subject during these investigations seemed justifiable.

RESISTANCE OF AMERICAN FOULBROOD SUSPENDED IN WATER TO HEATING

In preparing the spore material for heating a much diluted aqueous suspension of the disease material is drawn into capsules (fig. 8) made from glass tubing of small bore. After being sealed in a flame they are immersed in a water bath having a temperature and for the period desired in the heating.¹ Cultures then are made using a loopful of the suspension from the capsule and brood-filtrate-egg-yolk-suspension agar.

The results of the experiments given in the following table indicate the approximate amount of heating that is necessary for the destruction of the spores suspended in water.

Fig. 8.—Capsule used in determining the thermal death point of spores.



TABLE I.—Preliminary experiments indicating the thermal death point of the spores of *Bacillus larvae* suspended in water²

FIRST SET OF EXPERIMENTS. DISEASE MATERIAL RECEIVED FROM AMERICA

Temperature.		Period of heating.	Results as shown by cultures, October, 1913.
° C.	° F.	Minutes.	
0	0	0	Numerous spores alive (check).
90	194	20	Many spores not killed.
94	201	10	One spore not killed.
96	205	10	All spores killed.
97	207	10	Do.
98	208	10	Do.
99	210	10	Do.
100	212	5	Do.
100	212	10	Do.

¹ About two minutes are allowed for the suspension within the capsule to reach the temperature of the water outside before time is reckoned.

² Fractions are omitted in this paper, the nearest whole number being given.

SECOND SET OF EXPERIMENTS. DISEASE MATERIAL RECEIVED FROM ENGLAND.

Temperature.		Period of heating.	Results as shown by cultures, October, 1913.
$^{\circ}$ C.	$^{\circ}$ F.	Minutes.	
0	0	10	Numerous spores alive (check).
91	196	10	Spores not killed, about $\frac{1}{10}$ as many as in check.
95	203	10	All but 2 spores killed.
96	205	10	All spores killed.
98	208	10	Do.
99	210	10	Do.
100	212	1	Spores not killed, about $\frac{1}{2}$ as many as in check.
100	212	2	All but 100 spores killed.
100	212	3	All but 20 spores killed.
100	212	4	Do.
100	212	5	Do.

THIRD SET OF EXPERIMENTS. DISEASE MATERIAL RECEIVED FROM FRANCE.

Temperature.		Period of heating.	Results as shown by cultures, October, 1913.
$^{\circ}$ C.	$^{\circ}$ F.	Minutes.	
0	0	10	Numerous spores alive (check).
90	194	10	Spores not killed, almost as many as in check.
92	198	10	Spores not killed, about $\frac{1}{2}$ as many as in check.
93	199	10	All but 30 spores killed.
94	201	10	All but 100 spores killed.
96	205	10	All but 12 spores killed.
98	208	10	All but 1 spore killed.
99	210	10	All spores killed.

FOURTH SET OF EXPERIMENTS. DISEASE MATERIAL RECEIVED FROM CUBA.

Temperature.		Period of heating.	Results as shown by cultures, January, 1915.
$^{\circ}$ C.	$^{\circ}$ F.	Minutes.	
92	198	10	Numerous spores not killed.
93	199	10	Do.
94	201	10	Fewer spores not killed.
95	203	10	Do.
96	205	10	Do.
97	207	10	Fewer alive than at 96 $^{\circ}$ C.
98	208	10	Fewer alive than at 97 $^{\circ}$ C.
99	210	10	About 12,000 spores not killed.
100	212	10	About 200 spores not killed.
100	212	11	Do.
100	212	12	Do.

From Table I it will be observed that all the spores taken from the American sample were killed by heating at 96 $^{\circ}$ C. for 10 minutes; that all of those from the English sample were also killed at 96 $^{\circ}$ C. in 10 minutes; that all of those from the French sample were killed at 99 $^{\circ}$ C. in 10 minutes; and that all of those from the Cuban sample were killed at 100 $^{\circ}$ C. in 11 minutes. Spores from the different samples varied, therefore, in their resistance to heating, those from the American and English samples being slightly less resistant than those from the French one which showed in turn slightly less resistance than those from the Cuban sample.

By a comparison of the results it will be observed that many spores among those heated were destroyed at 90 $^{\circ}$ C. in 10 minutes and that the percentage remaining alive when the higher temperatures were used rapidly decreased. The results indicate also that by increasing the temperature the time required to destroy the spores is decreased and vice versa.

Further studies relative to the thermal death point of the spores were made on disease samples received from different localities in the United States. The technique followed is similar to that given on page 22. The results obtained are summarized in Table II:

TABLE II.—*Variation in thermal death point of American foulbrood spores from different localities in the United States*¹

Temperature.		Period of heating.	Source of samples.										
			Wash.	Minn.	Nebr.	Ohio.	Ill.	Colo.	Wis.	Penn. 4529.	Penn. 4507.	Ohio 4519.	Mont.
° C.	° F.	Minutes.	—	—	+	+	+	+	+	+	+	+	+
100	212	10	—	—	—	—	—	—	—	—	—	—	—
100	212	5	—	—	—	—	—	—	—	—	—	—	—
100	212	1	—	—	—	—	—	—	—	—	—	—	—
98	208	10	—	—	—	—	—	—	—	—	—	—	—
95	203	10	—	—	—	—	—	—	—	—	—	—	—

¹ The minus sign in Tables II and IV indicates that the spores were not all killed and the plus sign that all of them were killed.

The results in Table II show that in none of the 11 cases were all of the spores killed in 1 minute at 100° C.; in 5 of the cases they were all killed in 5 minutes at this temperature while in 6 of them they were not. In two instances out of the 11 they were not killed in 10 minutes at 100° C. They were killed, however, at this temperature in 11 minutes. It will be seen also that in no instance were all of the spores killed at 95° C. in 10 minutes, but in 5 of the 11 cases all of them were killed at 98° C. within the 10 minutes.

By these results it is shown again that the spores of different samples do vary in their resistance to heat. No conclusion is drawn regarding the cause, environmental or otherwise, for this variation.

TIME A FACTOR IN THE DESTRUCTION OF AMERICAN FOULBROOD SPORES BY HEAT

Suspensions of scales of American foulbrood in water were heated for different periods at 100° C. In the following table are recorded the results obtained when the spores from the Cuban sample were used:

TABLE III.—*Period of heating American foulbrood spores a factor when 100° C. is used*

Temperature.		Period of heating.	Results as shown by cultures, February, 1915.
° C.	° F.		
		Minutes.	
100	212	0	25,000 spores present (estimated).
100	212	1	4,000 spores not killed (estimated).
100	212	5	148 spores not killed.
100	212	6	220 spores not killed.
100	212	7	248 spores not killed.
100	212	8	44 spores not killed.
100	212	9	7 spores not killed.
100	212	10	14 spores not killed.
100	212	11	All spores killed.
100	212	12	Do.
100	212	13	Do.
100	212	14	Do.
100	212	15	Do.

From Table III it will be noted that there were about 25,000 colonies in the check cultures. When a similar suspension was heated only about 4,000 spores remained alive after 1 minute at 100° C., 148 after 5 minutes, 44 after 8 minutes, 14 after 10 minutes, and none after 11 minutes. The conclusion is reached, therefore, that the time element is a factor in the destruction of the spores of American foulbrood by heat.

These results further show that the spores of different samples vary in their resistance to heat. It is interesting to note that by heating the disease material at 100° C. for one minute, more than 80 per cent of the spores were killed, and in 5 minutes, more than 99 per cent were destroyed.

In Table IV are summarized results which indicate further the value of the time element in the destruction of the spores by heat. In this instance spore material from 6 different localities was used, the heating being done at 95° C. with the spores suspended in water:

TABLE IV.—*Effect of the time element when 95° C. is used in heating American foulbrood spores*

Temperature.		Period of heating.	Source of samples.					
			Cuba.	Colo.	Ohio 4504.	N. Y.	Ohio 4519.	Minn.
°C.	°F.	Minutes.						
95	203	12	—	—	—	—	—	—
95	203	15	—	—	—	—	—	—
95	203	20	—	—	—	—	—	—
95	203	20	—	—	+	+	+	+
95	203	50	—	—	+	+	+	+
95	203	60	+	+	+	+	+	+

From Table IV it will be observed that the spores from all of the six samples studied resisted in an aqueous suspension a temperature of 95° C. for 15 minutes. Spores from the Minnesota sample were destroyed in 20 minutes at 95° C., those from the Ohio and the New York samples in 40 minutes; and those from the Colorado and Cuban samples in 60 minutes. The time element is shown again to be an important factor in the destruction of American foulbrood spores.

These results show also, as was shown above, that the spores contained in different samples vary as to their thermal death point.

Other experiments were made showing the resistance of the spores of *Bacillus larvae* suspended in water to heat. At 93° C. (199° F.) spores from a Minnesota sample were destroyed in one hour, those from a Colorado sample in 1½ hours, while those from the resistant Cuban sample were not all killed in 3 hours. Experiments using Cuban, Colorado, and Pennsylvania samples showed in each instance that numerous spores remained viable after 2 hours' heating at 90° C. (194° F.).

RESISTANCE OF AMERICAN FOULBROOD SPORES TO HEAT WHEN SUSPENDED IN HONEY

The effects of heating American foulbrood spores suspended in water are shown above. When suspended in honey a different degree of resistance is to be expected. The technique used to obtain facts relative to such resistance is quite similar to that described (p. 22) for the experiments in which the spores were heated in aqueous suspensions; instead of water, however, the spores were suspended in honey¹ or honey diluted with water. For testing whether or not the spores had been killed by the heating, cultures were used in some instances and bees in others.

In Table V are summarized some of the results obtained when the spores suspended in honey diluted with an equal volume of water were heated and tested by cultures:

TABLE V.—*American foulbrood spores heated in diluted honey*¹

Temperature.		Period of heating.	Origin of sample.	Cultural results. April-May, 1915.
° C.	° F.	Minutes.		
98	208	10	Nebraska.....	Numerous spores not killed.
98	208	10	New York.....	Do.
98	208	20	do.....	Do.
98	208	20	Nebraska.....	Do.
98	208	20	Illinois.....	Do.
100	212	10	New York.....	Do.
100	212	20	do.....	Do.
101	214	8	Washington State.....	Do.
101	214	10	Colorado.....	Do.
102	216	8	Cuba.....	Do.
103	217	3	Washington State.....	Do.
104	219	3	do.....	Do.
105	221	3	Cuba.....	About 500 spores not killed.

¹ The altitude of the laboratory in Washington being nearly sea level the boiling temperature of water is almost 100° C. The higher temperatures recorded in this table and the following one were obtained by immersing the capsule containing the suspension in a solution of sodium chlorid and other salts.

Table V shows that numerous spores were alive after being heated in a suspension of honey diluted with equal parts of water for 20 minutes at 100° C. The spores of American foulbrood are not destroyed by heat as readily, therefore, when suspended in diluted honey as when suspended in water.

Experiments were made in which the spores were heated suspended in undiluted honey and tested by the cultural method. Table VI indicates the nature of the results obtained:

¹ The honey used was purchased at the market in sealed cans and was from the crop of the year preceding the experiments.

TABLE VI.—*American foulbrood spores heated in undiluted honey*

Temperature.		Period of heating.	Origin of sample.	Cultural results. April-May, 1915.
° C.	° F.	Minutes.		
100	212	10	Cuba.....	Numerous spores not killed.
100	212	10	Washington State.....	Do.
100	212	10	Ohio.....	Do.
100	212	20	Cuba.....	Do.
100	212	20	Washington State.....	Do.
100	212	20	Ohio.....	Do.
103	217	25	Washington State.....	Do.
105	221	20	do.....	Do.
105	221	20	Cuba.....	Do.
107	225	20	do.....	Do.
107	225	30	do.....	Do.
107	225	40	do.....	Do.

From the results given in Table VI it will be observed that in every instance the spores suspended in honey resisted 100° C. for more than 10 minutes. It will be noted that numerous spores were alive after being so heated for 20 minutes. In fact they resisted 105° C. for 20 minutes and more. It is shown that numerous spores from the resistant Cuban sample were still alive after 40 minutes heating at 107° C. When suspended in honey, therefore, spores are much more resistant to heat than when suspended in water (p. 22) or when suspended in diluted honey (p. 26).

While the thermal death point has not been definitely determined for the spores suspended in honey, the results obtained indicate that the point was being approached by the experiments of Table VI. It was found that the spores suspended in honey were killed readily by heating in the autoclave at 15 pounds pressure, being destroyed, in fact, by the time this pressure was reached. In making these tests the suspension in test tubes was brought to 100° C. before being placed in the autoclave. After the heating cultures were made.

SPORES HEATED IN HONEY AND FED TO BEES

A further set of experiments was made in which American foulbrood material suspended in honey was heated to 100° C. and tested by the inoculation of colonies of bees. In performing the experiments a concentrated aqueous suspension of the disease material was added to hot honey, which is handled more readily than the cooler honey, until each 15 c.c. of honey suspension contained the material from 3 to 5 scales. This was then distributed in test tubes, each tube receiving about 15 c.c. of the suspension. These tubes were heated as were the aqueous suspensions in experiments reported above (p. 22), by immersing them in water. After heating, the contents of the tube were added to sirup and colonies were inoculated. In Table VII some of the experiments performed are summarized:

TABLE VII.—*American foulbrood spores heated in honey and fed to bees*

Date of inoculation.	Temperature.		Period of heating.	Results of inoculation.
	° C.	° F.	Minutes.	
1916				
Aug. 25.....	100	212	10	American foulbrood produced.
Sept. 12.....	100	212	12	No disease produced.
Do.....	100	212	15	Do.
Do.....	100	212	18	Do.
Aug. 25.....	100	212	20	Do.
Sept. 12.....	100	212	25	Do.
Aug. 11.....	100	212	30	Do.
Aug. 25.....	100	212	30	Do.
Do.....	100	212	45	Do.
Oct. 11.....	100	212	90	Do.
Do.....	100	212	120	Do.

It will be noted from Table VII that American foulbrood was produced after the scale material had been heated in honey for 10 minutes at 100° C., but was not produced when this temperature was maintained for 12 minutes or longer. The amount of heating required to prevent American foulbrood in the experiments recorded in this table is not as great as might have been expected from an examination of Table VI. The results tend to indicate that the virulence might have been affected somewhat before the spores were killed. Sufficient data to prove the point, however, are yet lacking.

From the various experiments relating to the thermal death point of American foulbrood spores recorded on the foregoing pages, it will be observed that 100° C. maintained for 10 minutes, with an exception now and then, is sufficient to kill all of the spores when suspended in water. It will be observed also that 98° C. applied for 10 minutes will do this in many instances and that 95° C. is sufficient in some cases. It is shown, furthermore, that a large majority of the spores are killed at 90° C. in 10 minutes and also that a very large number of them are killed at 100° C. in 1 minute.

That a difference exists in the thermal death point of American foulbrood spores was expected. A difference is seen in the spores from different samples, in those from different larvæ or pupæ in the same sample, and indeed in those of the same larvæ or pupæ. The maximum difference, when expressed in terms of degrees of temperature, between the most resistant spores of any two samples among those studied, the temperature being maintained for 10 minutes, is approximately 7° C.; and when expressed in time, the temperature being maintained at 100° C., is approximately 7 minutes. These differences are for the spores suspended in water. Suspended in honey a greater difference is to be expected. That still greater variations exist than those observed in these studies is most certain. To meet such differences the beekeeper has been urged to employ for the destruction of the spores in practical apiculture somewhat

more heat than the minimum amount that is required as determined by experimental studies.

RESISTANCE OF AMERICAN FOULBROOD SPORES TO DRYING

That the American foulbrood spores are able to withstand much drying has long been realized by beekeepers. Scales of American foulbrood obtained in 1907 from colonies in which the disease had been produced through experimental inoculation were stored in the laboratory. Each succeeding year for 9 years tests were made relative to the viability of the spores in this material. In 1916 they were still alive and as resistant to heat and as virulent as at any previous time. It is most likely that they would have withstood the drying at room temperature for a very much longer period than the 9 years.

RESISTANCE OF AMERICAN FOULBROOD SPORES TO DIRECT SUNLIGHT

RESISTANCE OF AMERICAN FOULBROOD SPORES WHEN DRY TO DIRECT SUNLIGHT

In conducting experiments relative to the resistance possessed by spores of *Bacillus larvae*, when dry, to the direct rays of the sun, a heavy aqueous suspension is made of the scale material. This is spread in a thin film in Petri dishes and allowed to dry, the amount of disease material in each dish being equal to that in from 3 to 5 scales. The dry layer of disease material is then exposed to the direct rays of the sun and after different intervals of time cultures are made to determine whether the spores are viable. Table VIII gives a summary of the experiments made:

TABLE VIII.—*Resistance of spores of Bacillus larvae when dry to the sun's rays*

Date of experiment.	Period of exposure	Results as shown from cultures.
1916		
Aug. 31.....	Hours. 2	Numerous spores not killed.
Aug. 28.....	4	Many spores not killed.
Sept. 5.....	5	Do.
Do.....	7	Several spores not killed.
Do.....	10	Few spores not killed.
Sept. 6.....	11	Do.
Sept. 23.....	12	Many spores not killed.
Sept. 19.....	29	Several spores not killed.
Sept. 25.....	38	A dozen spores not killed.
Aug. 23.....	28	All spores killed.
Aug. 23.....	37	Do.
Sept. 23.....	41	Do.
Sept. 25.....	41	Do.
Sept. 16.....	44	Do.
Do.....	61	Do.
Sept. 25.....	79	Do.

From Table VIII it will be observed that all of the spores were killed by the direct rays of the sun in from 28 to 41 hours. It is natural to expect that the period required would depend upon the

date and time of exposure and somewhat upon the thickness of the film of disease material exposed. The climatic conditions during August and September, the time of the experiments, were naturally favorable for the destruction of bacteria by sunlight. The exposures were made only when the sky was clear, preference being given to the middle portion of the day.

REISISTANCE OF AMERICAN FOULBROOD SPORES WHEN SUSPENDED IN HONEY TO DIRECT SUNLIGHT

The technique used is as follows: A concentrated aqueous suspension of spore-containing material is added to honey in Petri dishes, each dish receiving the disease material equal to that of from 3 to 5 scales. These are exposed to the direct rays of the sun. The tops are used with the dishes to prevent robbing by bees. After different periods of time the contents of a single dish are added to sirup and fed to a colony free from disease. A set of experiments made is summarized in Table IX.

TABLE IX.—*Spores of American foulbrood in honey exposed to the sun*

Date of experiment.	Period of exposure.	Results of inoculation.
1916.		
July 13	Hours. 6	Large amount of American foulbrood produced. Moderate amount of disease produced.
July 15	13	
	Weeks.	
July 26	2	Scattering cells of diseased brood.
Aug. 25	4	Considerable diseased brood.
Sept. 1	5	Do.
Aug. 10	4	No disease produced.
Aug. 18	5	Do.
Sept. 14	6	Do.
Do.	8	Do.

The data given in Table IX show that the spores of American foulbrood when suspended in honey were destroyed by the direct rays of the sun in from 4 to 6 weeks. As the suspension in each dish contained the disease material of from 3 to 5 scales it is evident from the results obtained that many of the spores must have been destroyed in a comparatively short period.

It will be readily appreciated that here again the period required for the destruction of the spores will vary greatly with the intensity of the sun's rays to which the honey suspension is subjected. In these preliminary experiments the period of exposure represents the entire time from the beginning of the exposure to the time of inoculation. There were days during the exposure on which the sun shone a great deal, others on which it shone very little, and still others on which it did not shine at all. The comparatively low temperature of the honey suspension attained during the exposure to the sun could not have been an important factor in the destruction of the spores.

RESISTANCE OF AMERICAN FOULBROOD SPORES TO FERMENTATION

A few preliminary experiments relative to the effect of fermentative processes on the spores of American foulbrood were made. The processes involved concern chiefly the sugar splitting and the proteolytic enzymes. In experiments relative to the former, the scale material was suspended in a 20 per cent aqueous solution of honey and, in those relative to the latter, it was suspended in a 1 per cent aqueous solution of peptone. In each case a small bit of soil was added to inoculate the suspending solution still further. These suspensions, respectively, were distributed in test tubes and allowed to undergo fermentation. Observations were made at incubator and outdoor temperatures. The outdoor temperature was that which obtained in an empty hive body covered, and standing in the apiary at the time of the year shown by the dates of the experiments. After intervals reckoned in days colonies free from disease were inoculated, each with a suspension from a single tube. The experiments are summarized in Table X:

TABLE X.—*Resistance of the spores of Bacillus larvae to fermentation*

Date of experiment.	Nature of the suspension.	Period.	Temperature.	Results of inoculations.
1916.		<i>Days.</i>		
Aug. 14..	Honey.....	26	Outdoors.....	American foulbrood produced.
Sept. 9...	do.....	53	do.....	Do.
Aug. 11..	do.....	24	Incubator.....	Do.
Sept. 9...	do.....	53	do.....	Do.
Aug. 14..	Peptone.....	26	Outdoors.....	Do.
Sept. 9...	do.....	53	do.....	Do.
Aug. 11..	do.....	24	Incubator.....	Do.
Sept.	do.....	53	do.....	Do.

From Table X it will be seen that in the presence of fermentative processes in the honey solution and in the peptone solution the spores were alive and virulent after 53 days at incubator and at outdoor temperatures. It is quite probable that they would have remained so for a very much longer period.

RESISTANCE OF AMERICAN FOULBROOD SPORES TO CHEMICAL DISINFECTANTS

While a mass of data was obtained relative to the effect of chemical agents on the spores of American foulbrood, the results are still considered as being preliminary in nature. In conducting the experiments a suspension of disease material in an aqueous solution of the disinfectant was used. This was drawn into capsules ¹ (fig. 9)

¹ The ampules used are made from glass tubing of small bore by heating and drawing it into three bulbs. The two intermediate constricted portions are wrapped with cotton. After being sterilized the ampules are filled with the spore-containing suspension sealed and placed at different temperatures. Incubator, room, and outdoor temperatures were employed. At the time of making the cultures the ampule is broken at the two intermediate constrictions and the spore-containing suspension used in making the inoculations is obtained from the intermediate bulb. By this method an immersion of the spores in the solution for the entire period is assured.

and sealed. After different intervals of time the suspension was cultured, using brood-filtrate-egg-yolk-suspension agar.

The results show that spores of American foulbrood were alive after being in suspension in 1, 2½, and 5 per cent aqueous solutions of carbolic acid (commercial) for months at room, outdoor, and ice-box temperatures, respectively. The maximum period during which any suspension was kept at ice-box temperature was 32 months. At incubator temperature the period during which the spores remain alive in 5 per cent carbolic acid is better reckoned in weeks than months. In 5 and 10 per cent solutions, respectively, of formalin (37 per cent formaldehyde) it was found that they were viable after 6 hours, and in a 20 per cent solution they were alive after 30 minutes. While the spores were alive in the formalin suspensions after these periods, the evidences obtained indicate that the chemical death point was being reached. Mercuric chlorid was resisted for days in 1 to 1000 and 1 to 500 solutions, respectively.



FIG. 9.—Capsule used in determining the resistance of spores to chemical disinfectants.

Inasmuch as the spores of American foulbrood resist the action of carbolic acid for more than a month under fairly favorable conditions for their destruction, this agent could scarcely be used with profit in practical apiculture. As the destruction of the spores with formalin is a question of hours only, it is possible in well-selected cases that use could be made of this agent. Since mercuric chlorid in strengths ordinarily used is resisted by the spores for days and furthermore is such a violent poison, its value as a disinfectant in American foulbrood is evidently limited. The general conclusion in regard to chemicals as disinfectants is, therefore, that they offer very little promise as a practical means for the destruction of the spores of American foulbrood.

EFFECT OF DRUGS ON AMERICAN FOULBROOD

Divers experiences have been reported by beekeepers relative to the value of drugs in the treatment of the bee diseases. The fact that the spores of *Bacillus larvae* possess a marked resistance to chemical disinfectants tends to discourage hope that such substances would be of much therapeutic value when employed as drugs in American foulbrood. Such a conclusion, naturally, would not follow necessarily. Some data relative to the effects of drugs on this disease have been obtained through experimental inoculations using betanaphthol, U. S. P.; carbolic acid (phenol), C. P.; oil of eucalyptus,

U. S. P.; formic acid, C. P.; salicylic acid, U. S. P.; salol (phenyl salicylate, U. S. P.); and quinin (bisulphate of quinin, U. S. P.).

In making the inoculations a suspension of scale material in water is added to medicated honey and colonies free from the disease are fed. The different drugs are used in different proportions. Honey, rather than sirup, is employed since the bees will take the drugs in higher proportions when in honey than when in sirup. The strength that they will take varies somewhat with the conditions present. The higher proportions recorded in Table XI summarizing the experiments approximate the maximum amount that can be employed:

TABLE XI.—*Indicating the effect of drugs on American foulbrood*

Date of experiment.	Drugs.	Strength.	Results of inoculation.
1916.			
July 11	Betanaphthol.....	1:2000	American foulbrood produced.
May 29	do.....	1:1000	
June 5	do.....	2:1000	
July 11	Carbolic acid.....	1:2000	
June 20	do.....	1:1000	
Do..	do.....	2:1000	
May 29	do.....	10:1000	
Do..	Oil of eucalyptus.....	4:1000	
July 11	Formalin.....	3:1000	
Do..	Salicylic acid.....	1:2000	
May 29	do.....	1:1000	
June 5	do.....	2:1000	
July 11	Salol.....	1:2000	
May 29	do.....	1:1000	
June 5	do.....	2:1000	
July 11	Quinin.....	2:1000	
May 29	do.....	3:1000	
June 5	do.....	10:1000	

From Table XI it will be seen that American foulbrood was produced in all cases in which colonies were fed a suspension of diseased material in honey medicated with betanaphthol, carbolic acid, eucalyptus, formic acid, salicylic acid, salol, and quinin respectively in the proportions noted. In some of the experiments medicated sirup free from the spores was fed to the inoculated colony on a few successive days following the inoculation, and in some instances both preceding and following it. Whether these treatments with the medicated sirup produced any effect on the infection—positive or negative—was not determined definitely.

The results thus far obtained indicate that the drugs cited here can not be depended upon, for the present at least, in the treatment of American foulbrood. They do not preclude the possibility, however, that other drugs might be used with profit, but they do emphasize the fact that beekeepers should make sure that the value of a drug has been clearly demonstrated before it is used.

The results recorded on the foregoing pages relative to the resistance of American foulbrood spores to heat, drying, fermentation, sunlight, chemical disinfectants, and drugs, it will be observed, are only approximate from a strictly technical viewpoint. For practical purposes, however, they are in most instances entirely adequate. In using any of these results in devising means for the destruction of the spores in practical apiculture the time element determined by the experiments should be somewhat increased in each instance.

MODES OF TRANSMISSION

Observations made during these studies point to certain paths by which American foulbrood is most likely to be transmitted. The evidences obtained tend to support certain views which have been entertained by beekeepers and to negative others which have been suspected by some as possible. Inasmuch as the disease may be produced in larvæ by feeding a colony *Bacillus larvæ* in pure cultures, or from decaying remains of brood dead of the disease, it would seem that the portal of entry of the virus is somewhere along the alimentary tract of the larva. The fact leads at once to the suspicion that the food of bees contaminated with disease material is a very probable source of infection. Were the water supply likewise contaminated naturally it also would be a probable source of infection. Two prerequisites for the appearance of American foulbrood in a colony are (a) larvæ of the feeding age, and (b) a sufficient amount of disease material in the food or water supply of bees. A small amount of brood or a heavy flow of nectar, therefore, would tend to reduce the likelihood of colony infection under conditions otherwise favorable for infection.

Bees manifest a tendency to remove brood dead of American foulbrood as shown by the remains of partially removed larvæ and pupæ dead of the disease. The removal is done piecemeal and is accomplished more readily when the brood is recently dead than when the decaying remains are at all viscid or dry. Were the fate of the removed fragments definitely known much more could be said concerning the spread of the disease in the colony. It has been observed that a small amount of infection—a dead larva or pupa here and there—may be present in a colony for months, a year, and even longer, without causing a heavy infection in it. There is considerable evidence to support the belief that occasionally in cases of light infection the disease may disappear unaided by treatment. Such a phenomenon frequently takes place in sacbrood and indeed should be expected to occur now and then in American foulbrood. It should be emphasized that such a course for the disease, if it occurs at all, is unusual. Although American foulbrood

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EUROPEAN FOULBROOD

By

G. F. WHITE, Specialist in Insect Diseases

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INTRODUCTION

European foulbrood is an infectious disease of the brood of bees caused by *Bacillus pluton*. It is characterized by the death of brood during its uncapped stage and by the absence of any marked odor. The disorder has a wide distribution and is fairly well known to beekeepers. The losses sustained by the infected apiary vary from a slight weakening of the colonies in some instances to the destruction of all of them in others.

Practical apiarists have determined much concerning the disorder while pursuing their profession. The writer in an earlier paper (15)¹ referred to the nature and extent of the progress that had been made in the study of the disease from the laboratory point of view. The present paper deals with results which have been obtained from a continuation of the work. Among the problems considered are: The re-

¹ Figures in parentheses refer to "Literature cited," p. 34.

sistance of *Bacillus pluton* to heat, drying, sunlight, fermentation, and disinfectants; the effect of the disease on the colony and on the apiary; and the transmission, diagnosis, and prognosis of the disease. Work directly on the treatment of the disease has not been attempted by the writer. Naturally, however, any treatment that is devised, if it is to be efficient and at the same time economical, must be based upon results obtained from the solution of such problems as those which have received attention in these studies.

Results obtained from a study of the disease in the laboratory and in the experimental apiary form the basis of the discussions contained in the present paper. Since the disease encountered in nature is very similar to the one produced by artificial inoculation, the importance of the studies is at once evident.

The paper¹ will be of interest, it is believed, not only to the apiarist who may wish to apply the facts here determined in the pursuit of his profession, but also to the investigator whose desire primarily is a further study of the disease.

NAME OF THE DISEASE

The term "foulbrood" was quite generally used in the past, as it still frequently is, for the two infectious diseases now known in America as European foulbrood and American foulbrood. In 1885 when Cheshire and Cheyne (4) in England made their studies on foulbrood and described *Bacillus alvei*, evidently they were not convinced that there were two distinct diseases that were being called by the one name foulbrood. The disease studied by them is the one which is the subject of discussion in the present paper. In the names for the two diseases it will be observed that the word "foulbrood" is retained in both instances. To this "European" is added for the disease on which early laboratory studies were made by these Europeans (Cheshire and Cheyne).

Dr. William R. Howard (6), of Texas, in 1900, worked for a brief period with this disease, reached the conclusion that it was a new one, and referred to it by the names "New York bee disease," or "black brood." Work by Moore and White (11) in 1902 showed that the disease was not new, but was the foulbrood studied by Cheshire and Cheyne (4). The names "New York bee disease," or "black brood," therefore, were superfluous, and as their use would have added to the confusion that already existed they were discarded. Beekeepers, entomologists, and pathologists, as a rule, are more or less familiar with the terms "foulbrood" and "*Bacillus alvei*." Usually, however, the rosy foulbrood—American foulbrood—is the one that is thought of,

¹ The present studies are similar to those made by the writer on sacbrood (17), Nosema-disease (18), and American foulbrood (19). A reference to these papers may be found helpful where the discussions in the present one are especially brief. The investigations were completed in September, 1916, and the paper was submitted for publication in October, 1918.

and the one that frequently has been associated in the literature with *Bacillus alvei*. This is unfortunate. While *B. alvei* is not the cause of any bee disease, it occurs very frequently with European foulbrood and is found only seldom in the rosy disease. In using the names European foulbrood and American foulbrood it is possible, however, to avoid confusion by bearing well in mind the history of the disease.

HEALTHY LARVÆ OF THE AGE AT WHICH THEY DIE OF EUROPEAN FOULBROOD

Bees dying of European foulbrood do so during the larval stage.¹ Death may take place at any time from the fourth day of larval life to pupation. For convenience of description the brood of the age at which death from European foulbrood occurs is placed here in three groups. Groups 1 and 2 include the uncapped and group 3 the capped larvæ.

GROUP 1

The youngest larva (Pl. II, D, G) that dies of European foulbrood practically covers the bottom of the cell. It lies either on its right or its left side, with its dorsal portion extending to the lateral walls of the cell. Its form is C shaped with the anterior and posterior extremities almost together. Its color is bluish white with a glistening surface, presenting a pearly appearance. The body is more or less opaque, due largely to the adipose tissue. Folds and furrows divide the surface into segments. In health these are quite prominent and the entire larva is turgid in appearance.

With the unaided eye spiracles and tracheæ can be seen with difficulty, but by slight magnification they are readily observed. Most of the tracheæ, appearing as white lines, extend either dorsally or ventrally on the lateral side of the larva, but a distinct chain connecting them will be observed to extend at right angles to these.

GROUP 2

Healthy larvæ (Pl. III, D, G) slightly older than those described in Group 1 constitute Group 2. The larva now completely fills the bottom of the cell. The dorsal side pressing against the lateral side walls of the cell causes the contour of the body to be in general hexagonal. The tracheæ are seen less easily than in younger larvæ, while the color, glistening appearance, prominence of segments, and turgidity are similar to those of the younger larvæ described in Group 1.

By turning the larva so that its dorsal surface may be brought into view (Pl. III, A) there is observed a more or less transparent narrow

¹ The term larvæ as used in the present paper applies to the prepupæ as well as to earlier stages of the brood.

area along the dorsal median line extending nearly the length of the body. The contents of the stomach may be seen through this area. The color of the mass is due chiefly to the presence of pollen. It is usually some shade of yellow. The median area presents in its appearance a sharp contrast to the bluish-white, opaque portions on either side of it. Similar appearances are to be noted in the larvæ of Group 1.

The larva removed from the cell performs only slight movements, lies partly coiled, and is more or less turgid. The segments are prominent. When the body wall is torn there flows from the ruptured wall the clear larval blood, in which are suspended often fat and other tissue cells which give to it a somewhat milky appearance. The stomach, a transparent tube easily torn into segments, contains a mass of partially digested food, pollen constituting usually a conspicuous portion of it.

GROUP 3

Group 3 consists of capped larvæ. These are, therefore, larger than those described in Groups 1 and 2. In the group are included the larvæ which have spun a cocoon as well as those which have not. An endwise position in the cell may or may not have been assumed. The larvæ are seen in various positions. Not infrequently some portion of the dorsal surface is turned toward the observer, the narrow, median, transparent area being in evidence as in younger larvæ. Healthy larvæ occupying an endwise position are described in papers on sacbrood and American foulbrood (17, 19) and will not be referred to further at this time.

SYMPTOMS

In European foulbrood, as in other brood diseases, the colony as a whole and not the individual bee should be considered as the unit in the discussion of the symptoms of the disease. The description of the symptoms recorded in the present paper is based chiefly upon observations made on the disease produced through artificial inoculations. In making the studies in the experimental apiary observations made by beekeepers have been duplicated and new facts determined. It has been possible also to locate errors which have been made in discussions of symptoms of the disease.

GENERAL SYMPTOMS FROM A CASUAL EXAMINATION

Death of brood during the feeding stage, in uncapped cells, is a characteristic of European foulbrood. The brood nest in the disease usually presents an irregular appearance, capped cells and uncapped ones being found scattered irregularly over the brood frames, giving to them the "pepper box" appearance (Pl. I) often referred to by

beekeepers, a condition noticeable when the disease is fairly well advanced in the colony.

The dead larvæ lose their pearly whiteness and assume a yellowish color, later becoming brownish. This deepens often to a dark brown. The decaying remains are not characteristically ropy, as in American foulbrood. Marked viscosity is usually absent. When it is present the decaying mass can be drawn into threads but to a less extent than in the ropy disease. In advanced cases the disease may be accompanied by an odor, but in the writer's experience this never has been marked and never offensive.

As the disease in the colony advances, weakness becomes a symptom. In severe cases queenlessness may result from the infection. This, however, is by no means the rule.

SYMPTOMS MANIFESTED BY INDIVIDUAL LARVÆ SICK OR DEAD OF EUROPEAN FOULBROOD

Evidences of European foulbrood in the individual larvæ appear before and after death. The colony symptoms used most frequently in the diagnosis of the disease are largely post-mortem appearances of larvæ. Of much interest and frequently of considerable diagnostic value are the symptoms manifest by larvæ sick but not dead of the disease. For convenience in the description of the appearances of the sick or dead larvæ, the grouping used in describing the healthy larvæ (p. 3) is followed. The appearances of affected larvæ both living and dead are, of course, changing constantly. A description which is correct for one day or hour, it should be realized, is not likely to be entirely correct for the next.

GROUP 1

The youngest larvæ manifesting symptoms of European foulbrood are approximately 4 days old (Pl. II, A, B, C, E, F, H, I). In many cases at this stage of the disease a peristalsis-like movement of the body is marked and is readily observed by the unaided eye, but in others no such bodily movements are observed. The diseased larvæ at the time may be more transparent (Pl. II, B, H) than healthy ones of the same size. In such larvæ the tracheæ are quite prominent and more readily seen than in healthy ones. Occasionally numerous minute opaque areas are observed in these more transparent larvæ, giving to them a punctate appearance. Very often, however, this sign is not present. In many instances, indeed, no distinct symptom is observed until the larva approaches death. (Pl. II, A).

Larvæ (Pl. II, A, B, C, E, H, I) of this group dying or just dead of the disease lose their marked glistening appearance; their pearly whiteness gives way to a yellowish tint; the turgidity seen in healthy larvæ is diminished in the sick; and the folds and furrows indicat-

ing the segments of the body become less prominent. As the process of decay advances the yellowish hue changes, the color assuming a brownish tone. The segmental markings are less prominent, while the tracheæ often become quite distinct, appearing as white lines contrasted with the darker color of the larval remains (Pl. II, B). Not infrequently at this time there will be seen a chitinous envelope containing a watery-looking fluid in which is the larva proper (Pl. II, C; Pl. IV, A). The decay proceeds and the drying becomes evident. The larval mass settling upon the concave bottom of the cell causes the upper surface of the mass to be depressed about the center. At this stage the tracheæ not infrequently are seen distinctly in the drying mass. When the larval remains become dry they are known as the scale (Pl. II, F). The scales do not adhere closely to the cell and when removed are found to be thin and more or less circular in outline. They are convex and smooth on the side which was in contact with the bottom of the cell while the opposite surface—the one which, while in the cell, was toward the observer—is slightly roughened and concave.

GROUP 2

Larvæ (Pl. III) showing symptoms of European fowlbrood and classed in this group have reached a sufficient size to fill the deepest third or more of the cell. The yellowish tint appears in contrast to the bluish white of the healthy larvæ (Pl. III, D, G). Increased movement may or may not be observed. Before and after death the remains may assume one of a number of positions in the cell. Not infrequently a portion of the dorsal surface is turned toward the observer (Pl. III, B). Usually through the transparent area along the median dorsal line a whitish or yellowish-white mass is to be observed. This mass is within the stomach of the larva and contains a large amount of bacterial growth (Pl. VIII, a, b, c) consisting very largely of *Bacillus pluton*. Often before death this mass is seen to move within the stomach in response to the peristalsis-like movements of the body of the larva.

At the time of death the larva usually occupies some unnatural position, being more or less curled up and lying upon the floor of the cell (Pl. III, C, E, F, H, I). Lessened turgidity, a relative dullness of the surface appearance, and a yellowish tint are present. Not infrequently the two ends of the larva are directed more or less toward the bottom of the cell and some portion of the dorsal surface is toward the opening of it (Pl. III, E, H, I). Among the dead larvæ will be found some with one end directed toward the bottom, and the other toward the mouth of the cell, the body occupying a more or less spiral position against the side walls and floor of the cell (Pl. III, F).

Later the dead larval remains assume a brownish tint which deepens to varying shades as decay continues and drying takes place. During the early part of the decay, the firmness of the body wall permits the removal of the larva intact from the cell. Later, however, it offers but little resistance and is easily ruptured. The decaying mass before drying often attains a certain amount of viscosity. Sometimes it is of a doughy consistency, at other times it is purulent or sputum-like, while at times it assumes a viscosity that will permit of its being drawn out to the extent of an inch or more. When the larval mass becomes dry it forms an irregular scale, usually brown in color, lying on the floor or side wall of the cell or both, but not adhering closely to them.

GROUP 3

A larva dying of European foulbrood after being capped may be found occupying one of many positions within the cell (Pl. IV, C, D, E; Pl. V, D, E, F, G, H). Dying before the two-day quiescent period that precedes pupation, the remains during decay and as a scale resemble in many respects those of larvæ described in group 2. The dry scales occupy usually an irregular position on the floor of the cell (Pl. IV, F, G). Dying during the two-day quiescent period, however, the scales (Pl. V, F, I) resemble very much those of larvæ dying at the same age of American foulbrood. The larval mass assumes the brownish hue which deepens as the decay advances, reaching a dark brown. Viscidity is present in the decaying larval mass, but the extent to which the decaying material may be drawn out is less than in American foulbrood. The scale is less brittle and more rubberlike.

At no time has the writer observed pupæ dead of European foulbrood. If they die of the disease it is a rare occurrence.

The removal of larvæ sick or dead of the disease is accomplished to a greater or less degree by adult workers. The larvæ are either partially or entirely removed. This is usually done piecemeal. In an infected colony will be found, therefore, the remains of larvæ of different ages (Pl. IV, B) and (Pl. V, A) in varying numbers.

ETIOLOGY

PREDISPOSING CAUSES

Age.—Infection in European foulbrood takes place during the feeding stage and at some time after the first day of larval life, the larvæ being more often 2 days of age, or older. Death takes place somewhat more than 2 days from the time of infection. As a rule, therefore, a larva has passed its fourth day of larval life before death from European foulbrood occurs. From this age to pupation larvæ may die of the disease. The writer has not encoun-

tered death among brood which has reached the pupal stage. Adult bees are not susceptible to infection.

Sex.—Worker, drone, and queen larvæ are all susceptible to infection with *Bacillus pluton* and any of these may die of European foulbrood.

Race.—Complete immunity from European foulbrood has not been found among the races of bees studied. Experimental work recorded in the present paper involved the use of at least five colonies of "tested Italians," two of "tested Carniolans," and two of "tested Caucasians." For the most part the bees used were "untested Italians," but among the colonies were a few common blacks. In all these strains the disease was readily produced through experimental inoculation. The examination of numerous samples of diseased brood received from beekeepers throughout the United States suggests that all races commonly kept by American beekeepers are susceptible to European foulbrood. The relative immunity of the different races has not been demonstrated by the studies. These facts, however, do not dispute the observation by practical beekeepers that some strains of bees show a greater colony resistance than others.

Climate.—From reports of studies made in Austria by Muck (12), in Denmark by Bahr (1), in England by Cheshire and Cheyne (4), in Germany by Zander (20), and in Switzerland by Burri (3), it is clearly evident that the disease discussed in the present paper occurs in these different countries. It has been encountered also in many sections of the United States and Canada. This distribution shows that the infection can exist under a variety of climatic conditions. The practical import of the fact is that the presence of European foulbrood in any locality can not be attributed entirely to the climate of the region.

Season.—Beekeepers have observed that European foulbrood occurs with greatest severity before midsummer rather than later in the season. The disease, it has been shown experimentally, can be produced, however, at any season of the year at which brood is being reared. Its severity at any given season is to be attributed, therefore, to environmental conditions rather than to the difference in the susceptibility of larvæ during the different seasons.

Food.—As in American foulbrood it is found that the cause of the disease in the colony is governed very little if at all by the quality of food gathered by bees. Indirectly, however, the quantity present in the hive or obtainable often does influence its course materially.

EXCITING CAUSE

That *Bacillus alvei* may be present in large numbers in brood dead of foulbrood was demonstrated by Cheshire and Cheyne (4) in 1885.

For a decade and a half following the observation the belief was quite general that this bacterium was the exciting cause of a bee disease. The view was then seriously challenged. In 1906 the only positive conclusion in regard to the relation between European foulbrood and *Bacillus alvei* that could be drawn by the writer (13) was that this species occurs in brood dead of the disease.

William R. Howard (6), of Texas, after a brief study of the disease reported in 1900 the presence of an organism which he called *Bacillus millii*. He cultivated the species apparently with ease. In 1904 Bahr (1) in Denmark found a small oval bacterium in a brood disease in which larvæ dying in uncapped cells are yellowish in color and not ropy in consistency. Burri (3) in 1906 encountered in his studies on the brood diseases a small bacterium which he referred to as *guntheri*-forms. The species was cultured and compared with *Bacterium guntheri* and found to be somewhat different. In 1907 Maassen (7) obtained from brood material cultures of a species which he named *Streptococcus apis*. White (14) in 1908 reported the presence of a small organism in European foulbrood which had refused to grow on artificial media. The species was not the one, therefore, with which the investigators just referred to had worked. That this organism might be the exciting cause of the disease was noted. Pending more information regarding it, the species was not given a name but was referred to as bacillus "Y." That this species bears a direct etiological relation to the disease was demonstrated in 1912 by the writer (15) and the name *Bacillus pluton* was then given to it.

As the cultivation of *Bacillus pluton* on artificial media had not been accomplished the conclusion that it is the exciting cause of European foulbrood was arrived at by eliminating all other possible agencies. The observations furnishing the proof appear in an earlier paper (15). By demonstrating *Bacillus pluton* to be the cause of the disease, *Bacillus alvei*, *Streptococcus apis*, *Bacterium eurydice*, and *Bacillus orpheus*, and still other species occasionally encountered, were thereby proven to be secondary invaders.

To eliminate the possibility of a filterable virus in European foulbrood 10 colonies were inoculated with filtrates obtained from aqueous suspensions of brood sick and dead of the disease. In six instances the Berkefeld N filter was used and in four the Pasteur-Chamberland F was employed. In no case was the disease produced. Studies recorded in the present paper on the resistance of *Bacillus pluton* to heating, drying, fermentation, and disinfectants show that when the virus of the disease is not destroyed this species is still alive. This fact is further evidence in support of the conclusion that the species *Bacillus pluton* is the virus of the disease.

BACILLUS PLUTON

An artificial medium for the cultivation of *Bacillus pluton* has not yet been devised. To accomplish this may or may not be a particularly difficult task. The media ordinarily used in the laboratory are not suitable. Bee-larvæ agar, brood-filtrate media, egg-yolk-suspension agar (19), and combinations of these have not thus far proved sufficient for the purpose. The species is an unusual one. The generic classification has not been determined definitely and this may not be possible until the proper condition for the artificial cultivation of the species has been supplied.

The morphology of *Bacillus pluton* is somewhat variable. In very early infection its form is that of a short rod in pairs or in chains, or possibly of a coccus with the individuals similarly arranged (fig. 1; Pl. VII, B). The length is then equal to or somewhat greater than



FIG. 1.—*Bacillus pluton*.

the breadth. In slightly later stages of infection the predominating form is that of a lancet-shaped coccus (fig. 1; Pl. VII, A), and in late stages this form is present almost exclusively. The lancet form occurs singly, varying greatly in size and having a length which approximates twice the width. The length is more often less than $1\ \mu$ than greater. The organism colors uniformly with the aniline stains, stains with iron hematoxylin, and is gram-positive. It does not

form spores. This is evidenced by the microscopic appearance and also by the thermal death point of the species. Its resistance to drying, disinfectants, and other environments is discussed later in the present paper.

Seven rabbits inoculated, six subcutaneously and one intraperitoneally, with a suspension of larvæ dead of European foulbrood proved to be refractory. Only a slight rise of temperature followed the inoculations and the weight was not materially affected. Six guinea pigs inoculated subcutaneously with similar material proved not to be susceptible to infection with the species. Four pigeons inoculated in the pectoral muscles and two white rats inoculated subcutaneously also proved refractory. In none of these inoculated animals were there any lesions of particular note produced.

Growth of *Bacillus pluton* in the infected larva begins close to the surface of the peritrophic membrane (Pl. VII, I) in contact with the food of the larva. As growth continues the bacterial mass extends toward the center of the lumen of the peritrophic sac (Pl. VII, K),

finally filling it more or less completely (Pl. VII, J). The growth does not always take place uniformly along the peritrophic membrane (Pl. VII, J), nor does it extend beyond it (Pl. VII, I, J, K), but is inclosed within the sac, the tissues of the larvæ not being reached. The multiplication of the organism after the death of the host, if, indeed, it takes place at all, is limited.

Secondary invaders, chiefly *Bacillus alvei*, *Bacterium eurydice*, *Streptococcus apis*, and occasionally *Bacillus orpheus*, and a few others, are encountered at various stages of the disease and during the decay of the larva. During the life of the larva these species also remain within the peritrophic sac.

BACILLUS ALVEI

Bacillus alvei (fig. 2; Pl. VII, D, F) is present very frequently and in very large numbers in larvæ dead of European foulbrood. The species was well described by Cheyne (4). Descriptions may be found elsewhere also (11, 13). It is readily recognized and may be differentiated easily from other spore-producing species occasionally encountered in the diseased brood.

Bacillus alvei is not the active cause of any bee disease. It seems probable, however, that it plays a rôle in European foulbrood, but the extent is not fully known. The species is present usually, if not invariably, in large numbers in the rubberlike scales (Pl. V, F, I), which resemble so much those of American foulbrood. The decayed larval mass, which forms the scale, before becoming dry is ropy in consistency similar to that of American foulbrood but to a less degree. It seems probable that this ropiness is due more or less directly to *Bacillus alvei*. On account of this viscosity the decaying mass, as well as the scales, are removed with greater difficulty than are most larvæ dead of European foulbrood. The result, as often observed, is that these brown viscid decaying larvæ or the rubberlike scales resulting from them are the only evidence that European foulbrood is present in the colony.

While *Bacillus pluton* in such larval masses and scales is often difficult to detect microscopically, its presence can be demonstrated through the experimental inoculation of healthy larvæ. Inasmuch as *Bacillus pluton* will live for a considerable period in the scales, it



FIG. 2.—*Bacillus alvei*. Spores free from rods and others within rods.

seems quite probable that the disease might in some cases be carried over for months or even over winter through the medium of these rubberlike scales.

It is of interest to know that the amount of disease resulting immediately from inoculations in which scale material is used is much less than when larvæ recently dead of the disease are used. This is true also of dead larvæ stored in Petri dishes compared with smears allowed to dry immediately from larvæ recently dead of the disease. These facts indicate a possible deleterious effect on *Bacillus pluton* of the secondary invaders multiplying in the decaying larvæ.

STREPTOCOCCUS APIS

It is most probable that *Streptococcus apis* is the species that was isolated from diseased brood by Burri (3) and referred to by him in 1906 as "*güntheri*-forms." Maassen described it in 1908 (8). The organism grows well at incubator, room, and refrigerator temperatures in most of the media ordinarily used in the laboratory. Its cultural characteristics suggest the micrococci rather than the streptococci. Confusion in some of the earlier investigations was due evidently to the resemblance of *Streptococcus apis* and *Bacillus pluton* morphologically. To this fact is due the chief interest in the species *Streptococcus apis*. When

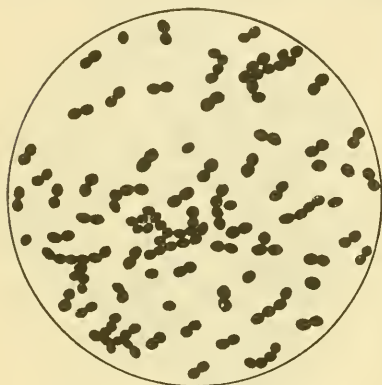


FIG. 3.—*Streptococcus apis*.

encountered in larvæ dead of European foulbrood it can be identified readily by culturing. The generic position of this species should be considered as being not altogether certain.

Occurrence.—*Streptococcus apis* is occasionally encountered in larvæ dead of European foulbrood and often is present in large numbers.

Morphology.—It is more or less spherical (fig. 3; Pl. VII, E), occurring singly and in pairs with occasionally a chain of 2 or more pairs when grown in liquid media. In larval remains not infrequently the ends may be somewhat pointed.

Staining properties.—It colors uniformly and readily with the common stains, and retains the stain after Gram's method.

Glucose agar plate.—Within a day growth is visible. Colonies never become large. Surface colonies are usually less than 2 mm. They are circular with uniform outline and a well-defined border, are grayish by reflected and bluish by transmitted light, are smooth and convex, are moist and glistening in appearance, and are friable in consistency. When magnified the surface colonies appear light brown in color, and granular in structure, the density decreasing from the center to the periphery. Deep colonies appear dense, dark brown, and coarsely granular. They are in general lenticular to oval but are sometimes almost spherical in form.

Glucose gelatin plate.—At refrigerator temperature and within 3 days, the surface colonies begin to liquefy the gelatin, each liquefied area appearing somewhat as a minute drop of water.

Agar slant.—In one day numerous gray colonies cover the inoculated surface.

Bouillon.—Within a day the medium is uniformly and moderately clouded.

Fermentation.—In glucose, lactose, saccharose, levulose, maltose, and mannite bouillons, a uniform clouding of the media occurs. The growth takes place in both arms of the tube, but is heavier in the open one. Considerable acidity, but no gas, is produced.

Milk.—Milk is rapidly coagulated. Digestion of the coagulum follows. In from 3 to 5 days more than one-half has been changed. Within 24 hours the color is discharged in litmus milk, except at the top of the medium. In other respects it is like the plain milk.

Potato.—No visible growth. That growth in the potato water takes place is confirmed by microscopic examination.

Gelatin stab.—Liquefaction along the line of puncture is appreciable after one day. In four days a cylinder of liquefied gelatin 1 cm. in diameter surrounds the original line of puncture and soon extends to the walls of the tube.

Pathogenesis.—No disease results when the brood of bees is fed cultures of *Streptococcus apis* either by the direct or indirect method. A rabbit and two guinea pigs inoculated with a pure culture of *Streptococcus apis* were not susceptible to infection with the species.

BACTERIUM EURYDICE

The presence of this species in European foulbrood was pointed out by the writer in an earlier publication (15). Among the secondary invaders in larvæ infected with *Bacillus pluton*, *Bacterium eurydice* is one of the earliest to be found. It is often present in considerable numbers. In plating for the species the stomach contents from larvæ sick, but not dead, of the disease should be used. In studying this species cultures were isolated which in some respects differed from it. Whether these are different species or belong to a group of which *Bacterium eurydice* is a representative has not been definitely determined.

To isolate *Bacterium eurydice* the plating has been done with glucose agar. Incubation must be carried out at room temperature. Growth of the species is always slow and never luxuriant. Under favorable conditions colonies are visible after one day. To preserve cultures they must be renewed frequently.

Occurrence.—*Bacterium eurydice* is frequently present in larvæ sick or recently dead of European foulbrood.

Glucose agar plate.—To the naked eye the surface colonies are slightly convex, smooth, and glistening. They are from 1 to 2 mm. in diameter, cir-



FIG. 4.—*Bacterium eurydice*.

cular and uniform in outline. The color is bluish by transmitted and grayish by reflected light. Under a two-thirds objective they are a light brown, and are finely granular near the periphery, but more coarsely granular near the center.

Morphology.—The rod (fig. 4; Pl. VII, C) is small and slender with slightly rounded ends, occurring usually in pairs or singly. It is nonmotile and no spores are produced.

Staining properties.—It is stained easily and uniformly with the ordinary aniline stains and is Gram-negative.

Oxygen requirements.—Growth is better in the presence of air than in anaerobic conditions.

Bouillon.—Growth takes place slowly, producing a uniform cloudiness with no pellicle. After a week or more a somewhat viscid sediment is present.

Sugars.—Growth in the sugar media is slow, variable, and never luxuriant. Both arms may be clouded. Glucose or levulose when added improves a medium. Fermentation with gas does not take place in any of the sugars. A noticeable amount of acid is formed when glucose and levulose are used, the other sugars being less affected. A 1 per cent honey solution supports a moderate growth. Brood filtrate as a rule improves media.

Milk.—In plain and litmus milk no changes are visible.

Potato.—Growth on potato is slow. When present, the culture is for the most part grayish in color.

Gelatin stab.—A bluish gray growth appears slowly along the line of inoculation. No liquefaction follows.

Pathogenesis.—No ill results are observed when cultures of *Bacterium eurydice* are fed to healthy colonies of bees. A rabbit inoculated subcutaneously with a pure culture proved to be refractory.

BACILLUS ORPHEUS

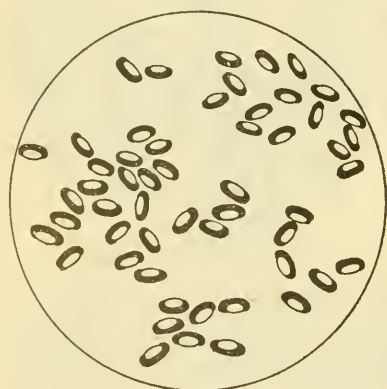


FIG. 5.—*Bacillus orpheus*: Spore formation.

The name *Bacillus orpheus* was given to an interesting species occasionally encountered in European foulbrood (15). In one instance the species was found very widely distributed in an apiary in which heavy losses were being sustained from the disease. In this case the

dead larvæ when dry were stonelike in character, the petrified remains breaking like so much marble. Usually the species is met with in a less number of the affected larvæ. It can be readily identified from its morphology and cultural characteristics. A description of the species has been made by McCray (9). An organism similar to *B. orpheus* in many respects has been described by Laubach (5) and named *Bacillus laterosporus*.

The organism is a motile spore-bearing rod with a few peritrichic flagella. Spore formation begins in a few hours on the surface of the agar at incubator temperature, the rod swelling toward the center and becoming fusiform. Soon, as determined from stained preparations, the spore is seen occupying one side

of the rod with the protoplasm distributed along the opposite side and the two ends (fig. 5; Pl. VII, H). The rod, together with the spore within it, measures about 2.4μ in length and 1.2μ in width. This relation of spore and rod persists in cultures on a solid medium for a long period, especially at room temperature. Good growth, no gas, and only slight changes in reaction occur in the sugar media. A slight coagulum forms in the milk which is slowly digested. Gelatin is rapidly fluidified.

Bacillus orpheus is not pathogenic for the brood of bees when inoculated by feeding either by the direct or indirect method. Silkworm larvæ succumb following inoculation by feeding and also by puncture.

TECHNIQUE¹

Artificial conditions for the successful cultivation of *Bacillus pluton* have not yet been obtained. That this can be achieved by further study is not at all improbable. Without having accomplished this, it has been possible, however, to make the studies on the biology of the parasite that were most desired. This was done through experimental work, using the larvæ of bees. The inoculations were made by feeding a suspension of the organism in sugar sirup.

Two methods were employed in making the feedings, which will be referred to here as (a) the indirect method, in which the colony is inoculated, and (b) the direct method, in which only a few larvæ are inoculated. Cane sugar and water were used in preparing the sirup in the proportion approximately of 3 to 2. This solution was then brought to the boiling point.

From 5 to 10 diseased larvæ furnish sufficient infective material when the indirect method is followed. These, after being picked from the brood frame, are thoroughly crushed, added to about 300 c. c. of the cooled sirup, and fed to a colony.² When the suspension contains the living virus, symptoms of European foulbrood appear in 3 days following the inoculation. The earliest evidence of disease is manifested by sick rather than dead larvæ (p. 5). Often fragments of larvæ (Pl. IV, B) are found upon examination of the brood nest.

In the direct method *Bacillus pluton* is taken from the stomachs of infected bees. Sick rather than dead larvæ are preferred for obtaining the virus free from the body tissues. By the use of dissecting needles and with a little care the stomach contents (Pl. VIII) can be pulled out of the blind end of the organ (15). The virus-containing material thus obtained is triturated with water and the aqueous suspension is added to sirup. The suspension of *Bacillus pluton* in a thin sirup is used in making the inoculation. Larvæ about 2 days old are especially desirable for the direct method. The inoculation is made by adding a small amount of the suspension to

¹ The technique in general which was found to be satisfactory for bee-disease studies is detailed to some extent in the sacbrood paper (17).

² The experimental colony is described in earlier papers (17, 18).

the food of the larvæ by means of a capillary pipette made from glass tubing of small bore. Care must be exercised in thus feeding the larvæ. Too much of the suspension will often float the larva. There is danger also that it will be changed in position mechanically by means of the feeding pipette. In either event the chances are that such larvæ will be removed subsequently by the bees. Considerable larval food already in the cell is advantageous. This method has proved to be especially useful in much of the experimental work recorded in the present paper. It has the advantage of being both economical as to the number of colonies needed, and definite. Dur-

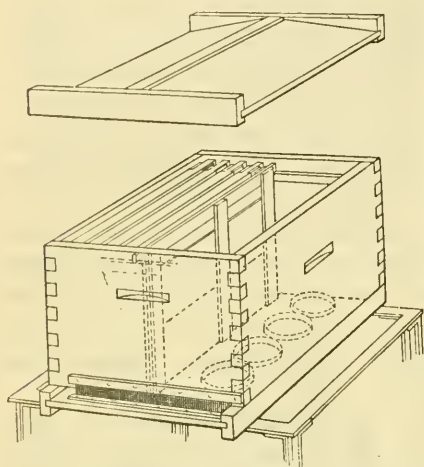


FIG. 6.—Experimental hive, having 4 Hoffman frames, a division board, Petri dishes as feeders, the entrance nearly closed with wire cloth, and the opening on the side of the hive body occupied by the frames. (Author's illustration.)

ing the third day following the hour of inoculation symptoms of European foulbrood will be observed if infection is produced. By the fourth day frequently all of the infected larvæ will have been removed by the bees. Symptoms of European foulbrood infection manifested by larvæ sick rather than dead have proved to be especially useful for experimental purposes in these studies.

During most of the time that experimental studies are being made it is necessary to have fresh diseased material at hand. A supply can be maintained by using one or more colonies for this purpose. Repeated inoculations of the col-

ony usually must be made at intervals of a few days or after longer periods, depending on its condition and the need for the virus. The indirect method is especially indicated in inoculating these colonies.

Frequently colonies which have been employed in European foulbrood experiments can be used again for further experiments on the disease. This must be done with some care, however. The condition of the brood always should be noted before an inoculation is made. European foulbrood colonies serve very well the purpose of experimental colonies for the other brood diseases and for *Nosema*-disease. In fact, not infrequently during these studies experiments on two or more of the diseases were in progress in a colony at the same time.

The apiary (Pl. VI) used in the experimental work with European foulbrood was the same as the one employed in the study of sacbrood (17), *Nosema*-disease (18), and American foulbrood (19). The hive (fig. 6) and the experimental colonies, where they were not the

same, were similar to those used in the other studies. The method of making the inoculations was also similar. The colonies were, therefore, in the open and the bees had free access of flight. The same precautions taken to minimize robbing, swarming, absconding, and drifting of bees were observed in the experiments with this disease as with the other diseases. All hives which had housed European foulbrood colonies were flamed before they were used again to be certain that there would be no infection from such a source. Whether the queens used had been in diseased colonies need not give one any concern. Further reference to the technique followed in the present studies will be made as the experiments are discussed.

THERMAL DEATH POINT OF *BACILLUS PLUTON*

The result of the experiments recorded by the writer in an earlier paper (16) shows that when suspended in water the thermal death point of *Bacillus pluton* is approximately 63° C., the period of application being 10 minutes. Further experiments have been conducted in which the organism was suspended in honey and heated. After being heated, healthy larvæ are inoculated by feeding, using the direct or-pipette method. Table I summarizes the experiments made:

TABLE I.—Resistance to heat of *Bacillus pluton* suspended in honey

Date of inoculation.	Temperature.		Period of heating.	Results of inoculation.
	° C.	° F.	Minutes.	
June 15. 1915.	67	153	10	European foulbrood produced.
Do.	70	158	10	Do.
Do.	75	167	10	Do.
June 22.	76	169	10	Do.
Do.	78	172	10	Do.
Sept. 22.	79	174	10	No disease produced.
June 15.	80	176	10	Do.
June 18.	80	176	10	Do.
Sept. 27.	81	178	10	Do.
June 19.	85	185	10	Do.
Do.	90	194	10	Do.

The results given in the foregoing table show that the thermal death point of *Bacillus pluton* suspended in honey is approximately 79° C., maintained for 10 minutes.

RESISTANCE OF *BACILLUS PLUTON* TO DRYING

In conducting experiments relative to the effect of drying on *Bacillus pluton* the stomach contents (Pl. VIII) of larvæ sick or recently dead of European foulbrood are spread in a thin layer in Petri dishes or on slides. From time to time after the films are made healthy larvæ are inoculated by feeding a suspension of the drying larval material suspended in a weak sirup solution. When no in-

fection results the germ is considered as having been destroyed. Observations have been made on the virus kept at incubator, room, outdoor, and refrigerator temperatures and shielded from the light in each instance. The experiments conducted with *Bacillus pluton* in these environments are summarized in Tables II, III, IV, and V which follow:

TABLE II.—Resistance of *Bacillus pluton* to drying at incubator temperature

Date of inoculation.	Period of exposure.		Results of inoculation.
	Months.	Days.	
1914.			
July 3.....		10	European foulbrood produced.
July 10.....		17	Do.
July 17.....		24	Do.
July 25.....	1	2	Do.
Aug. 3.....	1	7	Do.
Aug. 15.....	1	17	Do.
Sept. 1.....	2	0	Do.
Sept. 16.....	2	11	Do.
Sept. 29.....	3	0	Do.
1915.			
June 29.....	9	10	Do.
July 13.....	12	2	Do.
July 9.....	12	0	No disease produced.
Sept. 20.....	14	18	Do.
Sept. 17.....	14	20	Do.
1916.			
Sept. 8.....	24	0	Do.

TABLE III.—Resistance of *Bacillus pluton* to drying at room temperature

Date of inoculation.	Period of drying.		Results of inoculation.
	Months.	Days.	
July 25, 1914.....	1	1	European foulbrood produced.
Sept. 16, 1914.....	1	21	Do.
Sept. 1, 1914.....	2	8	Do.
Sept. 28, 1914.....	2	21	Do.
Sept. 29, 1914.....	3	0	Do.
Oct. 6, 1914.....	3	14	Do.
Jan. 29, 1915.....	9	10	Do.
July 9, 1915.....	12	6	Do.
Aug. 3, 1914.....	11	13	No disease produced.
June 22, 1915.....	11	15	Do.
June 25, 1915.....	11	18	Do.
Aug. 9, 1915.....	12	2	Do.
Sept. 17, 1915.....	14	10	Do.
Sept. 20, 1915.....	14	18	Do.
Sept. 8, 1916.....	24	0	Do.
Do.....	36	0	Do.

TABLE IV.—Resistance of *Bacillus pluton* to drying at outdoor temperature

Date of inoculation.	Period of drying.		Results of inoculation.
	Months.	Days.	
Sept. 2, 1914.....		33	European foulbrood produced.
Sept. 16, 1914.....		47	Do.
Oct. 13, 1914.....		74	Do.
May 26, 1915.....	9	21	Do.
June 19, 1915.....	10	18	Do.
May 17, 1915.....	13	17	Do.
Aug. 3, 1915.....	12	3	No disease produced.
Aug. 17, 1915.....	12	17	Do.
June 23, 1916.....	23		Do.

TABLE V.—Resistance of *Bacillus pluton* to drying at refrigerator temperature

Date of inoculation.	Period of drying.		Results of inoculation.
	Months.	Days.	
Oct. 17, 1915.....	.....	26	European foulbrood produced.
Sept. 18, 1916.....	3	28	Do.
May 3, 1916.....	6	12	Do.
June 23, 1916.....	8	0	Do.
May 26, 1916.....	8	2	Do.
June 23, 1916.....	9	0	Do.
July 31, 1916.....	10	7	Do.
Sept. 18, 1916.....	10	18	Do.

From Table II it will be observed that *Bacillus pluton* in a dry film made from the contents of infected larvæ resisted drying at incubator temperature for approximately one year. Table III shows that at room temperature, other conditions being similar, the resistance is approximately equal to that at incubator temperature. At outdoor temperature, as shown by Table IV, the resistance is again approximately the same. At refrigerator temperature, Table V, the experiments do not include the period at which *Bacillus pluton* is destroyed. In 10 months the organism was still viable and the results of the inoculations indicate from the character of the infection produced after such a period that at refrigerator temperature *Bacillus pluton* will remain alive for a longer period than at the other temperatures studied.

RESISTANCE OF BACILLUS PLUTON WHEN DRY TO DIRECT SUNLIGHT

In experiments relative to the resistance of *Bacillus pluton*, when dry, to the direct rays of the sun, smears are made of the contents of stomachs of European foulbrood larvæ in Petri dishes or on slides, and after becoming dry are exposed to the direct rays of the sun. After intervals reckoned in hours inoculations are made by feeding, using the direct method. Infection resulting from such inoculations shows that the drying has not killed the organism. In Table VI experiments performed in this connection are summarized:

TABLE VI.—Results of inoculation with *Bacillus pluton* in a dry film exposed to direct sunlight

Date of inoculations.	Period of exposure.	Results of inoculations.
	Hours.	
July 21, 1914.....	3	European foulbrood produced.
Sept. 18, 1913.....	6	Do.
July 31, 1914.....	7	Do.
Sept. 22, 1915.....	8	Do.
July 21, 1914.....	10	Do.
Sept. 27, 1915.....	14	Do.
Aug. 7, 1914.....	15	Do.
July 21, 1914.....	16	Do.
Aug. 7, 1914.....	20	Do.
Sept. 10, 1915.....	20	Do.
Sept. 25, 1915.....	21	Do.
July 22, 1914.....	23	Do.
Sept. 8, 1915.....	27	Do.

TABLE VI.—Results of inoculation with *Bacillus pluton*, etc.—Continued

Date of inoculations.	Period of exposure.	Results of inoculation.
	<i>Hours.</i>	
Sept. 20, 1915.....	21	No disease produced.
Sept. 24, 1915.....	23	Do.
Sept. 14, 1915.....	24	Do.
Aug. 16, 1915.....	26	Do.
Sept. 14, 1915.....	26	Do.
Sept. 13, 1915.....	31	Do.
Sept. 20, 1915.....	38	Do.
Aug. 3, 1915.....	40	Do.
Sept. 14, 1915.....	44	Do.
Aug. 16, 1915.....	46	Do.
Aug. 23, 1915.....	63	Do.
Sept. 14, 1915.....	95	Do.

Observations recorded in Table VI show that *Bacillus pluton* in a dry film made from the contents of the stomachs of larvæ sick or recently dead of European foulbrood resists the direct rays of the sun for from 21 to 31 hours.

RESISTANCE OF BACILLUS PLUTON IN WATER TO DIRECT SUNLIGHT

In performing the experiments relative to the effect of direct sunlight on *Bacillus pluton* suspended in water, an aqueous suspension of the contents of stomachs of infected larvæ is exposed, in a Petri dish with the top removed, to the direct rays of the sun. After intervals reckoned in hours inoculations of healthy larvæ are made to determine whether the organism is viable. The direct method is used. Experiments made in this connection are summarized in Table VII:

TABLE VII.—Resistance of *Bacillus pluton* suspended in water exposed to the direct rays of the sun

Date of inoculation.	Period of exposure.	Results of inoculation.
	<i>Hours.</i>	
Aug. 21.....	1	European foulbrood produced.
Do.....	2	Do.
Aug. 16.....	2	Do.
Aug. 8.....	3	Do.
Aug. 9.....	3	Do.
Aug. 16.....	3	Do.
Aug. 24.....	3	Do.
Sept. 13.....	4	Do.
Aug. 18.....	5	Do.
Aug. 16.....	5	No disease produced.
Sept. 14.....	5	Do.
Aug. 17.....	6	Do.
Aug. 20.....	6	Do.
Sept. 14.....	7	Do.
Do.....	7	Do.
Do.....	8	Do.
July 28.....	9	Do.
Aug. 20.....	10	Do.
	18	Do.

Table VII shows that *Bacillus pluton*, when suspended in water and exposed to the direct rays of the sun, was destroyed in from 5 to 6 hours.

RESISTANCE OF *BACILLUS PLUTON* IN HONEY TO DIRECT SUNLIGHT

Experiments were made to determine the resistance of *Bacillus pluton* when suspended in honey to the direct rays of the sun. In these experiments a honey suspension of the organism obtained from the stomachs of infected bees is exposed to the sun in a Petri dish with the top removed. After intervals, reckoned in hours, inoculation tests are made using healthy larvæ and the direct method. Table VIII contains a summary of the experiments performed:

TABLE VIII.—Resistance of *Bacillus pluton* suspended in honey and exposed to direct sunlight

Date of inoculation.	Period of exposure.	Results of inoculation.
1915.	<i>Hours.</i>	
Aug. 24.....	1	European foulbrood produced.
Do.....	2	Do.
Do.....	3	Do.
Aug. 3.....	3	No disease produced.
Aug. 20.....	3	Do.
Sept. 13.....	3	Do.
Sept. 19.....	4	Do.
Aug. 20.....	5	Do.
Sept. 14.....	5	Do.
Do.....	6	Do.
Sept. 11.....	7	Do.
Sept. 14.....	8	Do.
Do.....	9	Do.
Sept. 23.....	10	Do.

It is shown by the experiments recorded in Table VIII that in direct sunlight *Bacillus pluton* was destroyed in from 3 to 4 hours.

The results obtained by the experiments summarized in the last three tables above, it will be noted, show that *Bacillus pluton* is susceptible to the destructive effects of the direct rays of the sun; that the resistance of the organism suspended in honey is about equal to its resistance when suspended in water; and when dry the resistance is considerably greater than when suspended in either water or honey. It is to be expected that the period required for the destruction of the organism by the rays of the sun will vary with the intensity of the rays at the time of the exposure. In the foregoing experiments clear days were chosen and preference was given to the middle of the day for the exposures.

RESISTANCE OF *BACILLUS PLUTON* TO FERMENTATION

In obtaining data relative to the resistance of *Bacillus pluton* to fermentation, the stomach contents of larvæ sick or recently dead of European foulbrood were suspended in a 10 per cent sugar (saccha-

rose) solution. A bit of soil was added to inoculate it further. Records were made on suspensions fermenting at incubator and room temperatures, respectively. Tables IX and X which follow summarize experiments made:

TABLE IX.—*Bacillus pluton* in a 10 per cent sugar solution fermenting at incubator temperature

Date of inoculation.	Period of fermentation.	Results of inoculation.
	<i>Days.</i>	
Aug. 12, 1916.....	3	European foulbrood produced.
June 26, 1916.....	5	No disease produced.
Sept. 2, 1916.....	7	Do.
Sept. 7, 1915.....	8	Do.
Aug. 9, 1915.....	10	Do.
June 30, 1916.....	15	Do.
July 5, 1915.....	15	Do.
Aug. 24, 1915.....	24	Do.

TABLE X.—*Bacillus pluton* in a 10 per cent sugar solution fermenting at room temperature

Date of inoculation.	Period of fermentation.	Results of inoculation.
	<i>Days.</i>	
June 30, 1916.....	9	European foulbrood produced.
July 17, 1915.....	10	Do.
Sept. 8, 1915.....	10	Do.
July 21, 1915.....	14	Do.
Aug. 25, 1916.....	16	Do.
July 8, 1916.....	17	Do.
Sept. 10, 1916.....	11	No disease produced.
July 5, 1916.....	14	Do.
Aug. 26, 1916.....	21	Do.
Aug. 3, 1915.....	27	Do.
Aug. 9, 1915.....	32	Do.
Aug. 25, 1915.....	49	Do.

The experimental results contained in Tables IX and X show that *Bacillus pluton* is destroyed in a fermenting solution. At incubator temperature the virus was destroyed in from 3 to 5 days, and at room temperature it was killed in from 11 to 21 days.

Similar experiments were made in which suspensions in 20 per cent honey solutions were allowed to ferment at outdoor temperature. The records obtained show that *Bacillus pluton* in this environment was still alive and virulent after one month.

RESISTANCE OF BACILLUS PLUTON TO PUTREFACTION

Suspensions of the contents of stomachs from larvæ sick or dead of European foulbrood were made in a 1 per cent peptone solution. Soil was added to inoculate it further. Putrefactive changes were allowed to take place at incubator and room temperatures, respec-

tively. In Tables XI and XII, which follow, are summarized the experiments performed:

TABLE XI.—*Bacillus pluton* in the presence of putrefactive processes at incubator temperature

Date of inoculation.	Period of putrefaction.	Results of inoculation.
	<i>Days.</i>	
June 30, 1916.....	9	European foulbrood produced.
Sept. 2, 1916.....	7	No disease produced.
Aug. 15, 1916.....	8	Do.
Sept. 7, 1915.....	13	Do.
July 5, 1916.....	15	Do.
Sept. 10, 1915.....	16	Do.
July 8, 1916.....	18	Do.
Aug. 23, 1915.....	19	Do.
Aug. 30, 1915.....	26	Do.

TABLE XII.—*Bacillus pluton* in the presence of putrefactive processes at room temperature

Date of inoculation.	Period of putrefaction.	Results of inoculation.
	<i>Days.</i>	
Aug. 4, 1914.....	8	European foulbrood produced.
July 17, 1915.....	10	Do.
July 5, 1916.....	14	Do.
July 23, 1915.....	16	Do.
Aug. 14, 1914.....	18	Do.
Sept. 17, 1915.....	18	Do.
Aug. 25, 1916.....	18	Do.
Sept. 2, 1916.....	26	Do.
Aug. 3, 1915.....	27	Do.
Aug. 28, 1916.....	21	No disease produced.
Sept. 1, 1914.....	35	Do.
Sept. 16, 1914.....	51	Do.
Aug. 12, 1916.....	52	Do.

As shown by Tables XI and XII *Bacillus pluton* is destroyed in the presence of putrefactive processes. At incubator temperature it resisted the effects of these processes for from 7 to 13 days and at room temperature for from 21 to 35 days.

During August and September, 1916, preliminary experiments were made testing the resistance of *Bacillus pluton* to putrefaction at outdoor temperature. The parasite was alive and virulent after 40 days. The maximum period during which it will remain so has not been determined.

VIABILITY OF BACILLUS PLUTON IN HONEY

Honey suspensions of *Bacillus pluton* from the stomach contents of larvæ sick or recently dead of European foulbrood were made and distributed in flasks each containing about 300 c. c. These were allowed to stand at room temperature shielded from the light. At intervals thereafter colonies free from the disease were inoculated

each with the contents of a single flask. A summary of the experiments is contained in Table XIII:

TABLE XIII.—*Resistance of Bacillus pluton in honey at room temperature*

Date of inoculation.	Period in honey.		Results of inoculation.
	Months.	Days.	
May 22, 1915.....		4	European foulbrood produced.
June 12, 1915.....		25	Do.
July 23, 1915.....	1	6	Do.
June 25, 1915.....	1	11	Do.
Aug. 23, 1915.....	1	15	Do.
Aug. 3, 1915.....	1	17	Do.
July 12, 1915.....	1	25	Do.
Aug. 23, 1915.....	2	7	Do.
Sept. 10, 1915.....	2	25	Do.
Aug. 16, 1916.....	3	0	Do.
May 19, 1916.....	7	0	No disease produced.
May 4, 1915.....	7	17	Do.
June 7, 1913.....	8	0	Do.
June 13, 1913.....	8	0	Do.
May 13, 1915.....	8	25	Do.
May 14, 1915.....	8	26	Do.
May 22, 1915.....	9	5	Do.
May 24, 1915.....	9	5	Do.
July 31, 1916.....	9	11	Do.
May 15, 1916.....	10	6	Do.

Experimental evidence recorded in Table XIII shows that the virus of European foulbrood when suspended in honey at room temperature ceased to be virulent in from 3 to 7 months.

VIABILITY OF BACILLUS PLUTON IN POLLEN

Preliminary experiments were made to determine the viability of *Bacillus pluton* in pollen. Pollen is removed from brood-comb, and an aqueous suspension of the organism obtained from the stomachs of larvæ sick or recently dead of the disease is added to it until a moderately thick, pastelike mass is obtained. This is distributed in Petri dishes and allowed to stand at room and refrigerator temperatures, respectively. After different intervals of time the contents of a single dish, after being suspended in water, are added to about 300 c. c. of sirup and the suspension is fed to a colony, using the indirect method. The results show that *Bacillus pluton* was virulent after 7 months at room temperature and for more than 10 months in the refrigerator. The maximum period during which the organism will remain alive in these two environments has not been determined.

RESISTANCE OF BACILLUS PLUTON TO CARBOLIC ACID

Preliminary experiments were made to determine the effect of carbolic acid on the virus of European foulbrood. An aqueous suspension of the contents of the stomachs of larvæ sick or dead of the disease is first made. A measured quantity of this suspension is added to an equal quantity of an aqueous suspension of carbolic acid

of a strength twice that desired in the experiment. After shaking, it is allowed to stand at room temperature. At intervals brood free from the disease is fed a bit of this suspension, using the direct method. Table XIV summarizes the experiments performed:

TABLE XIV.—*Effect of carbolic acid on Bacillus pluton*

Date of inoculation.	Strength of solution.	Period of suspension.	Results of inoculation.
	<i>Per cent.</i>	<i>Days.</i>	
Aug. 22, 1914.....		$\frac{3}{4}$	European foulbrood produced.
Aug. 14, 1914.....		1	Do.
July 3, 1915.....		4	Do.
Aug. 21, 1914.....		8	Do.
Sept. 4, 1914.....		18	No disease produced.
June 29, 1915.....	1	$15\frac{1}{2}$	European foulbrood produced.
July 3, 1915.....	1	4	No disease produced.
June 29, 1915.....	2	15	Do.
Aug. 22, 1914.....	2	$11\frac{1}{2}$	Do.
Aug. 14, 1914.....	2	1	Do.
Aug. 17, 1914.....	2	4	Do.
Aug. 25, 1914.....	2	4	Do.
Aug. 22, 1914.....	2	9	Do.
June 29, 1915.....	4	$15\frac{1}{2}$	Do.

¹ Hours.

The experiments outlined in Table XIV show that *Bacillus pluton* withstood a one-half per cent solution of carbolic acid for 8 days but not for 18 days; that it withstood 1 per cent for 5 hours but not for 4 days; and that it was destroyed by 2 and 4 per cent solutions, respectively, in less than 6 hours. Probably it is destroyed by these latter strengths in considerably less time than this.

It is seen by these preliminary experiments that *Bacillus pluton* is destroyed easily by carbolic acid as a disinfectant. As a drug, however, less can be expected of it, inasmuch as a strength twice that which the bees will accept in honey (Table XV) requires days to destroy the germ. While the fact does not furnish conclusive proof of the value of carbolic acid as a drug, it indicates what might be expected of it in the treatment of the disease.

In using the results recorded on the foregoing pages for the purpose of destroying the virus of European foulbrood and controlling the disease in practical apiculture, it must be borne in mind, as has been urged in the discussions on the other bee diseases, that due allowance must be made by the beekeeper for variations which always occur. These, however, are relatively slight and can be met readily. In the destruction of the virus through heating, for example, the temperature can be raised a few degrees above that which is found to be the minimum required, or the time can be extended somewhat. Similarly for the other destructive agencies the effectiveness of the process can be increased.

EFFECT OF DRUGS ON EUROPEAN FOULBROOD

Preliminary experiments have been made to obtain data relative to the effect of drugs on *Bacillus pluton*. In conducting the experiments a suspension of the stomach contents of larvæ sick or recently dead of European foulbrood is made in an aqueous solution of the drug. This is added to diluted honey and healthy brood is fed this suspension. In some instances the direct and in others the indirect method was followed. In Table XV are summarized the experiments which were performed:

TABLE XV.—*The effect of drugs on European foulbrood*

Date of experiment.	Drugs.	Strength.	Results of inoculation.
1916.			
July 11.....	Betanaphthol.....	1:2000	} European foulbrood produced.
May 31.....	do.....	1:1000	
June 7.....	do.....	2:1000	
July 11.....	Carbolic acid.....	1:2000	
June 21.....	do.....	1:1000	
Do.....	do.....	2:1000	
May 31.....	Oil of eucalyptus.....	4:1000	
July 11.....	do.....	4:1000	
June 7.....	Formic acid.....	1:1000	
July 11.....	do.....	3:1000	
Do.....	Salicylic acid.....	1:2000	
May 31.....	do.....	1:1000	
June 7.....	do.....	2:1000	
July 11.....	Salol.....	1:2000	
May 31.....	do.....	1:1000	
June 7.....	do.....	2:1000	
July 11.....	Quinin.....	2:1000	
May 31.....	do.....	4:1000	
June 7.....	do.....	10:1000	

It will be observed from Table XV that European foulbrood was produced in all cases in which larvæ were fed a suspension of *Bacillus pluton* in sirup medicated with betanaphthol, carboic acid, eucalyptus, formic acid, salicylic acid, salol, and quinin (bisulphate of quinin), respectively, in the proportions noted.

The strongest solutions of the drugs used in the experiments are in most instances approximately the maximum proportion of the chemical in honey that will be taken by the bees. These preliminary results indicate that drugs should not be depended upon, for the present at least, in the treatment of European foulbrood, and emphasize the fact that beekeepers should make sure that the value of a drug has been demonstrated fully before it is used.

TRANSMISSION OF EUROPEAN FOULBROOD

While there is yet much to be learned concerning the transmission of European foulbrood, the data at hand relative to this important phase in the study of the disease justify certain statements in regard to it. The disease can be produced experimentally by feeding a healthy colony the crushed larvæ sick or dead of the disease, suggesting that infection takes place by way of the alimentary tract.

Through the study of microtome sections of such larvæ, it has been conclusively proved that infection takes place in this way. The fact is naturally one of special moment in the solution of the transmission of the disease. There is a tendency on the part of adult bees to remove sick and dead larvæ from the brood comb. This is done largely at least in a piecemeal manner. Were the fate of the fragments removed known definitely the solution of the problem naturally would be aided greatly.

If infective material thus removed were fed to susceptible healthy larvae, disease would result. On the other hand should the fragments of diseased larvæ be stored with the honey of the hive or with the pollen, or consumed by the adult bees, or by larvæ later in the feeding stage, the chances that such material would ever reach susceptible larvæ to cause infection are very much reduced. Stored in honey the virus remains virulent only a few months (p. 24); in pollen, however, it remains virulent much longer (p. 24). Drying within the hive *Bacillus pluton* would probably remain alive more than a year (p. 19).

The chances that any portion of the infectious material of any given fragment, if it is removed entirely from the hive by the bees of the colony, and released from them, will be taken up by other bees and carried to healthy brood and cause infection are comparatively slight. If thus removed and exposed to the direct rays of the sun, the virus will be destroyed within a few hours (p. 19); or if subjected to fermentative or putrefactive processes it will be destroyed in a few weeks (p. 23). If *Bacillus pluton* is present in honey extracted from diseased colonies it will be destroyed within a few months while in storage (p. 24). It is seen, therefore, that in nature there are many means that destroy the virus of European foulbrood and thus limit the spread of the disease.

All of the colonies of the experimental apiary used in making the inoculations cited in the present paper had free access to the fields and there was no evidence at any time of the transmission of the disease from infected to healthy colonies. This fact supports the conclusion that the disease is not spread by way of flowers visited by bees from healthy colonies which had been visited previously by bees from diseased ones. The fact further indicates that if the disease is transmitted at all by way of the water supply of the bees, it takes place to a limited extent only. The fact still further indicates that if drones or straying or drifting workers transmit European foulbrood they do so to a slight extent only. If these observations are at variance with the experience of the practical beekeepers, as the writer has been informed that they are, they will probably be of particular interest.

Observations made during the present studies indicate that queens from European foulbrood colonies are not likely to transmit the disease when introduced into healthy colonies. The experiences further show, and the facts in general regarding the disease support the conclusions, that the infection will not be transmitted by the hands or clothing of the beekeeper, or by visitors to the apiary when the manipulations ordinarily practiced are followed. Tools and equipment used about the apiary are not to be feared unless they supply a source for robbing. Hives which have housed infected colonies are not likely to be a medium for the spread of the disease.

Robbing of infected colonies is the most fruitful source of infection. A colony weakened by disease (p. 5) becomes a prey for other bees. Infectious material is carried to other colonies, thereby transmitting the infection. Manipulations in the apiary, whereby brood combs from diseased colonies are placed in healthy ones, are another fruitful source for the transmission of the disease. Preliminary work¹ indicates that stored brood combs from European foulbrood colonies may transmit the disease after a considerable period.

The disease, it would seem, might be spread through the medium of honey from infected colonies. The danger from this source, however, probably has been overestimated at times (p. 23). That pollen stored in the comb would serve as a protection to *Bacillus pluton*, if the parasite were lodged with it, has been determined (p. 24).

DIAGNOSIS

The diagnosis of European foulbrood offers more difficulty than does that of either American foulbrood or sacbrood. It can usually be made, however, from the symptoms alone. Inasmuch as these symptoms (p. 4) are rather varied, much care should be exercised in diagnosing the disease.

The appearance of the adult bees does not aid in the diagnosis. A weak colony should arouse suspicion. Increased suspicion is justified when no other readily discernible cause for the weakness is to be observed. The disease may be present, however, in a strong colony. Such a case may be one of recent infection or one which late in the recovery from the disease has gained in strength. It may be, however, a colony which has suffered only a slight attack of the disease.

The following outstanding gross characters are often sufficient for a diagnosis: The dying of the brood before the time for capping (Pls.

¹ Brood combs were removed from European foulbrood colonies in October, 1914, and stored in the laboratory. In May, 1915, one frame of brood comb was placed in each of two colonies with the result that European foulbrood was produced in both instances. When a frame of the comb was placed in the colony in May, 1916, no disease resulted. After 6 months the combs were still able to transmit the disease; after 18 months they did not. These experiments are not sufficient to justify definite conclusions but are suggestive.

II, III, IV), the yellow hue of the larvæ more recently dead, and the brown shade of those longer dead, the irregularity of the brood (Pl. I), and the absence of a disagreeable odor.

Not infrequently, however, the diagnosis is not so simple. During recovery from the disease scales (Pl. V, F, I) of larvæ dying in capped cells may be the only remains of diseased brood to be found, all of the younger larvæ having been removed by the bees. These scales¹ are, as a rule, comparatively few in number and resemble somewhat those of American foulbrood, but would rarely be mistaken for those of sacbrood. In these cases a diagnosis can be made frequently by a microscopic examination alone. Cultures, however, are needed in some instances.

Special attention is needed in cases of early infection and in other instances where only a small amount of diseased brood in uncapped cells is present (Pl. I, A). The symptoms manifested by larvæ sick or only recently dead of the disease furnish often the readiest and most conclusive evidence of the presence of the disease. Larvæ of the age at which they comfortably fill the bottom of the cell exhibiting increased peristalsis-like movements of the body suggest European foulbrood. Increased transparency of larvæ of this age (Pl. II, B) is also suggestive. The presence of a white or yellowish-white mass within the stomach (midgut) as seen through the dorsal median line of the body is strong evidence of the presence of the disease. If on puncturing the body of larvæ nearly dead or only recently dead the contents of the stomach flows out as a fluid and more or less finely granular mass, the fact furnishes further evidence of European foulbrood.

A symptom which is pathognomonic of the disease is to be seen in larvæ that have been infected somewhat more than two days, but wherein the disease has not reached an advanced stage. The test (15) involves the removal of the stomach contents, which consist of a bacterial mass, together with a small amount of larval food and a clear envelope (Pl. VIII, a, b, c). The slight tension necessary to remove the contents stretches the envelope and breaks the whitish bacterial mass into a number of fragments.

¹ The number of larvæ that die of European foulbrood in capped cells after assuming the endwise position represents a very small percentage of the brood that dies of the disease. These remains may be found in practically all colonies in which the disease has been present for a sufficiently long period and in which a considerable amount of dead brood has resulted. Before becoming dry they are somewhat viscid and are less easily removed than are those of larvæ dying at an earlier age. These and the scales resulting from them are used in diagnosis principally (1) when the younger larvæ sick or dead of the disease have been removed, (2) when a demonstration of the presence of *Bacillus alvei* is desired, and (3) when both European foulbrood and American foulbrood infection is suspected. Such a double infection has been encountered in the writer's experience very rarely. In making diagnoses, therefore, after European foulbrood has been found in the sample American foulbrood is seldom looked for.

By one or more of these colony symptoms manifested by larvæ sick or only recently dead of the disease the experienced can diagnose European foulbrood definitely without a microscopic examination. The methods not only give definite results, but are also easy of application. They have been indispensable in much of the writer's experimental work and it is believed that the beekeeper will find them to be valuable in practical apiculture where other gross methods fail.

BACTERIOLOGICAL EXAMINATION

The findings from microscopic examinations and from cultures have been set forth in an earlier publication (10). These are always adequate for a definite diagnosis when a suitable sample is at hand. *Bacillus alvei* (p. 11) (fig. 2; Pl. VII, D, F) frequently overshadows all other species. In larvæ sick of the disease *Bacillus pluton* (Pl. VII, A, B) overshadows all others. With experience one learns to recognize this species in stained preparations. The individuals are seen frequently in groups. They are more or less lancet shaped, and a variation in size is often sufficient to be noticeable (fig. 1).¹ In larvæ nearly dead and in those only recently dead *Bacterium eurydice* (p. 13) (fig. 4; Pl. VII, C) is frequently encountered. *Streptococcus apis* (p. 12) (fig. 3; Pl. VII, E) occurs in a small number of cases. *Bacillus orpheus* (p. 14) (fig. 5; Pl. VII, H), *B. vulgatus*, and *B. mesentericus* are occasionally encountered. While *B. pluton* is present in all cases of European foulbrood, not infrequently in routine examinations it is so masked by the secondary invaders that the microscopic examination fails to reveal it. In many cases *B. alvei* and *B. orpheus* are recognized microscopically. Cultures are necessary for the differentiation of *B. vulgatus* and *B. mesentericus*. In many cases cultures are needed to differentiate *Strep. apis* and *B. pluton*. *Strep. apis* grows on the ordinary media, *B. pluton* does not.

DIFFERENTIAL DIAGNOSIS

AMERICAN FOULBROOD

American foulbrood is recognized by the death of larvæ in capped cells and of pupæ soon after transformation, the viscosity of the decaying remains of the brood, and the "foulbrood" odor which is frequently present. The presence of the spores of *Bacillus larvae* in large numbers and the absence of other species is conclusive proof of American foulbrood.

¹ Smears made from larvæ sick of European foulbrood and quite early in the course of the disease were selected in making a study of the morphology of *B. pluton*. These were stained with iron hematoxylin. In smears made from dead larvæ and stained with carbol fuchsin, as is usually done, the pointed ends and the more or less rod-shaped forms are less prominent than illustrated in figure 1.

SACBROOD

Sacbrood is recognized by the death of larvæ after capping, by the saclike appearance, the watery granular consistency of the larval remains, and the absence of viscosity. The absence of microorganisms characterizes the microscopic picture in sacbrood.

OTHER CONDITIONS

Conditions referred to as chilled brood, overheated brood, and starved brood must be differentiated from European foulbrood. This can usually be done with little difficulty by a comparison of the symptoms present with those of European foulbrood. The history of the case is of much value. Brood dying after being removed from the hive and before examination is made shows often an interesting similarity to European foulbrood. *B. alvei* and *B. pluton* are not found in these conditions. The absence of bacteria, or their presence in small numbers only, and a lack of uniformity of the species when present, characterize the bacteriological findings in these cases.

PROGNOSIS

There is no uniformity in the prognosis in European foulbrood. The diseased colony may recover completely from the infection, suffering only a slight loss in strength as a result of it; the colony may recover but sustain considerable loss; or it may die out entirely, as a result of the disease. The infection may spread only slightly to other colonies of the apiary or the entire apiary may become infected. The losses sustained vary from slight to total. The tendency for European foulbrood to disappear is greater after midsummer than before.

Whether a larva once infected ever recovers from this disease is not known, but the evidence at hand indicates that it may. This seems to be especially probable when the infection takes place during the latter part of the feeding period of the larva. Queen larvæ are susceptible to infection, but sufficient data are wanting from which to estimate the extent to which queenlessness may result from the disease. In experimental colonies queens have been reared in the presence of a considerable amount of European foulbrood infection.

The prognosis for the colony in the case of European foulbrood may be said, therefore, to vary from very good to very grave, many recovering entirely from the infection without treatment and without appreciable losses, while others rapidly decline and finally die out.

SUMMARY AND CONCLUSIONS

The following is a brief summary of facts regarding European foulbrood, together with some conclusions based upon them:

1. European foulbrood is an infectious brood disease of bees caused by *Bacillus pluton*.

2. All larvæ—worker, drone, and queen—are susceptible to the disease; adult bees are not.
3. Man evidently is not susceptible to infection with *Bacillus pluton* nor are the experimental animals.
4. As far as is known insects other than bees are not susceptible.
5. Brood can be infected by feeding the colony a suspension of crushed larvæ sick or dead of the disease. This is described in the present paper as the indirect method.
6. The virus contained in a single larva recently dead of European foulbrood will produce a considerable amount of disease when fed to a colony.
7. The larvæ can be infected also by a more direct method. A fraction of a drop of a suspension of the stomach contents of a larva sick of the disease added with a capillary pipette directly to the food surrounding the larva to be inoculated will result in infection.
8. *Bacillus pluton* gains entrance to the larva by way of the mouth. The growth and multiplication of the parasite take place within the stomach (mid-intestine) of the larva and do not, during the life of the larva, get beyond the peritrophic membrane. The tissues, therefore, are not invaded by it.
9. The secondary invaders in European foulbrood, *Bacillus alvei*, *Streptococcus apis*, *Bacterium eurydice*, and *Bacillus orpheus*, rarely, if ever, invade the tissues until the larva is dead or nearly so. In a few instances in microtome sections rod forms have been encountered in the act of invading the tissues of living larvæ. The species, however, was not determined definitely.
10. The period of incubation is slightly less than 3 days.
11. Brood is susceptible to infection at all seasons of the year.
12. More brood die of the disease during the first half of the brood-rearing season than during the second half.
13. The writer has examined samples of the disease from Canada and the United States. From written reports it seems quite certain that it occurs also at least in Denmark, England, Germany, France, and Switzerland.
14. Occurring as it does in this somewhat wide range of climatic conditions, the presence of the disease in any particular locality can not be attributed entirely to the prevailing climatic conditions.
15. The quality of food obtained by the bees does not affect greatly, if at all, the course of the disease in the colony, although the quantity may affect it to a variable extent.

16. Experimental colonies may be inoculated and kept in the apiary without transmitting the disease to others. This fact is of special importance, not only in connection with the technique of making studies on the disease, but also in the control of the malady.
17. The thermal death point of *Bacillus pluton* suspended in water is approximately 63° C. maintained for 10 minutes.
18. When suspended in honey *Bacillus pluton* is destroyed in 10 minutes at approximately 79° C.
19. Drying at room or incubator temperature *Bacillus pluton* remains alive and virulent for approximately one year.
20. When dry, *Bacillus pluton* resisted the direct rays of the sun for from 21 to 31 hours.
21. When suspended in water *Bacillus pluton* was destroyed by the direct rays of the sun in from 5 to 6 hours.
22. When suspended in honey and exposed to the direct rays of the sun *Bacillus pluton* was destroyed in from 3 to 4 hours.
23. In the presence of fermentative processes in a 10 per cent sugar solution *Bacillus pluton* was destroyed in from 3 to 5 days at incubator temperature and in from 11 to 21 days at room temperature.
24. In a fermenting honey solution outdoors *Bacillus pluton* was still alive and virulent after one month.
25. In the presence of putrefactive processes at incubator temperature *Bacillus pluton* was destroyed in from 7 to 13 days and at room temperature in from 21 to 35 days.
26. In a putrefying medium at outdoor temperature *Bacillus pluton* remained alive and virulent for more than 40 days. The maximum period has not been determined.
27. In honey at room temperature *Bacillus pluton* ceased to be virulent in from 3 to 7 months.
28. Mixed with pollen, *Bacillus pluton* remained alive and virulent for more than 7 months at room temperature and more than 10 months at refrigerator temperature, the maximum time not being determined.
29. In one-half per cent carbolic acid solution *Bacillus pluton* was destroyed in from 8 to 18 days; in 1 per cent it was destroyed in from 5 hours to 4 days, and in 2 and 4 per cent in less than 6 hours. The probability is that at these higher strengths of the solution minutes rather than hours are sufficient for the destruction of the virus.
30. Experimental evidence indicates that at the present time drugs should not be depended upon in the treatment of European foulbrood.

31. Robbing from diseased colonies of the apiary or from neighboring apiaries is the most likely manner in which European foulbrood is transmitted in nature.
32. Brood-combs containing diseased brood, if given to a healthy colony, serve as a medium for the transmission of the disease.
33. European foulbrood is not likely to be transmitted by queens or drones. Whether they ever do so has not been demonstrated.
34. As a rule a hive which has housed a European foulbrood colony should not be considered as a fruitful source of infection. The facts indicate that often such hives could be used with impunity for housing colonies without treatment. Flaming them inside certainly removes all danger.
35. The transmission of European foulbrood by way of flowers, visited by bees from diseased colonies and subsequently by those from healthy ones, is not to be considered as a likely source of infection. Whether the water supply is ever a source of danger is not known. It is evidently not a fruitful source.
36. The disease is not likely to be transmitted through the medium of the clothing or hands of the apiarist.
37. Tools and bee supplies in general do not serve as means for the transmission of the disease in the absence of robbing from such sources.
38. It is usually possible to diagnose European foulbrood from the symptoms alone. A definite diagnosis can be made from suitable samples by bacteriological methods.
39. The prognosis in European foulbrood varies from very good to exceedingly grave. The tendency for a colony to recover entirely from the disease is much greater than in American foulbrood.
40. Considered from the technical point of view, much is yet to be learned concerning European foulbrood. For practical purposes, however, it can be said that sufficient knowledge has been gained to make it possible for the beekeeper to devise a treatment which will be logical, efficient, and at the same time economical.

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EXPLANATION OF PLATES

PLATE I

Brood-combs containing larvæ that are sick and others that are dead of European foulbrood, showing the irregular appearance of the brood. About one-half natural size.

A.—The dead larvæ have all been removed. Some of the remaining larvæ are sick, others are not infected. The disease was produced by experimental inoculation.

B.—Many of the dead larvæ have not been removed. The comb had been out of the colony for a considerable period. The larvæ that are quite young showing abnormal position and appearance are not sick or dead of European foulbrood, but are so as a result of the comb being away from the colony. Disease was produced by experimental inoculation.

C.—The comb was taken from a colony in which the disease had appeared in nature and not as the result of artificial inoculation. Before being photographed the brood-comb had been out of the hive for a few days. Aside from the larvæ which are dead of European foulbrood, other larvæ present are dead from lack of attention by adult bees—starvation, exposure, and other causes.

PLATE II

A.—Live larva showing first symptoms of European foulbrood. The turgidity is slightly less than in a healthy larva (D).

B.—Live larva showing early symptoms of European foulbrood. The body is more transparent than that of a healthy larva (D). Small opaque areas give it a punctate appearance.

C.—Larva dead of European foulbrood contained within a chitinous envelope filled with a watery-appearing fluid.

D.—Healthy larva of the earliest age at which larvæ die of European foulbrood. Turgidity marked.

E.—European foulbrood larva which may or may not be dead. Surface less glistening than in healthy larvæ. Marked turgidity lost. Prominence of tracheæ not increased.

F.—Scale formed by drying of larvæ dead at early age. Prominence of tracheæ marked.

G.—View of healthy larva in normal position with roof of cell removed. Larva turgid. Surface glistening.

H.—Larva sick with European foulbrood. Lack of turgidity and increased prominence of tracheæ observed.

I.—European foulbrood larva which may or may not be dead. Less turgidity, a relative dullness in the surface appearance, and punctate condition present. Similar to E.

PLATE III

A.—Healthy larva immediately preceding the age at which the capping of the cell is done. Dorsal surface turned toward the observer. The narrow transparent area along the dorsal median line is prominent.

B.—Larva dead of European foulbrood of the same age as A. The turgidity, glistening surface, and transparent area are less marked.

C.—Larva dead of European foulbrood partly coiled and partly endwise in cell.

D.—Healthy larva near the age at which capping takes place.

E.—Dorsolateral view of a larva dead of European foulbrood. The ends are directed toward the bottom of the cell.

F.—Larva dead of European foulbrood. The body occupies a spiral position in the cell.

G.—Healthy larva approaching the age at which capping takes place.

H.—Lateral view of larva dead of European foulbrood seen with the roof of the cell removed. The ends are directed toward the bottom and the dorsal surface toward the mouth of the cell.

I.—Dead larva similar to H but having been dead somewhat longer.

PLATE IV

A.—Young larva dead of European foulbrood. The chitinous capsule and tracheæ are prominent.

B.—Fragments of young larva dead of European foulbrood, a portion having been removed by adult bees after its death.

C.—Lateral view of larva dead of European foulbrood, the roof of the cell having been removed. The ends in this instance are directed more or less toward the mouth of the cell.

D.—Lateroventral view of larva dead of European foulbrood. The body lies with the dorsal portion against the floor of the cell.

E.—Larva dead of European foulbrood lying on the floor of the cell in somewhat lengthwise position.

F.—Scale of European foulbrood larva which had occupied a somewhat spiral position in the cell.

G.—Scale of a European foulbrood larva which had occupied a position somewhat as shown in D. This scale and the one shown in F can be removed intact rather easily and without tearing the wall of the cell.

PLATE V

Larvæ (prepupæ) of bees dead of European foulbrood which had already assumed before death a lengthwise position in the cell.

A.—Fragment of European foulbrood soon after death. A portion of the larva has been removed by the adult bee.

B.—Entire cap of cell containing larva dead of European foulbrood.

C.—Punctured cap of cell containing the remains of a larva dead of European foulbrood.

D.—End view of larva dead of European foulbrood.

E.—End view of larva dead of European foulbrood, lying with its dorsal surface against the floor of the cell. Considerable drying of the remains has taken place.

F.—End view of scale of European foulbrood larva which had reached before death the age at which the endwise position in the cell is assumed.

G.—Ventral view of European foulbrood larva. Stage similar to D. Turgidity is lost to a large extent and the segmented markings are less distinct than in healthy larvæ.

H.—Larva which has been dead of European foulbrood for a longer period than illustrated in G. The ridge and furrows indicating the segments of the body are not marked.

I.—Scale of European foulbrood similar to F. The larva before death had reached the endwise position in the cell. These scales resemble very much those of American foulbrood. They are more easily removed, however, do not adhere so closely to the floor of the cell, and are more rubberlike in consistency, breaking less readily than those of American foulbrood.

PLATE VI

A view of the experimental apiary of 54 colonies in which the inoculation experiments made during the summer of 1915 were conducted.

PLATE VII

Photomicrographs illustrating the more commonly encountered bacteria in European foulbrood.

A.—*Bacillus pluton*: A smear from the stomach of a larva sick with European foulbrood. Note the paired forms and short chains. These forms are numerous in a recent infection, suggesting the organism in the process of multiplication. The lancet-shaped form is by far the predominant one in all later stages of the disease. $\times 1000$.

B.—*Bacillus pluton*: A smear from a larva quite recently infected. The multiplying paired forms are at this stage present almost exclusively. $\times 1000$.

C.—*Bacterium curydice*: Stained preparation from a pure culture on the surface of agar. $\times 1000$.

D.—*Bacillus alvei*: Stained preparation showing spores and spore formation. $\times 800$.

E.—*Streptococcus apis*: Stained preparation from a pure culture. $\times 800$.

F.—*Bacillus alvei*: The peculiar arrangement of the spores as sometimes seen. From a pure culture, the smear having been made by suspending the culture on the slide in normal salt solution. $\times 1000$.

G.—*Bacillus orpheus*: Stained preparation made from a pure culture only a few hours old. Grown on the surface of agar. $\times 1000$.

H.—*Bacillus orpheus*: Stained preparation showing spore formation. Note the stained portion along one side and about both ends of the spore. The stage is soon reached in a culture at incubator temperature. At room temperature it remains in this stage for a considerable period. $\times 800$.

I.—Longisection of a young larva showing early infection in European foulbrood. The bacterial growth is seen as a narrow black area just within the peritrophic membrane on one side of the food mass.

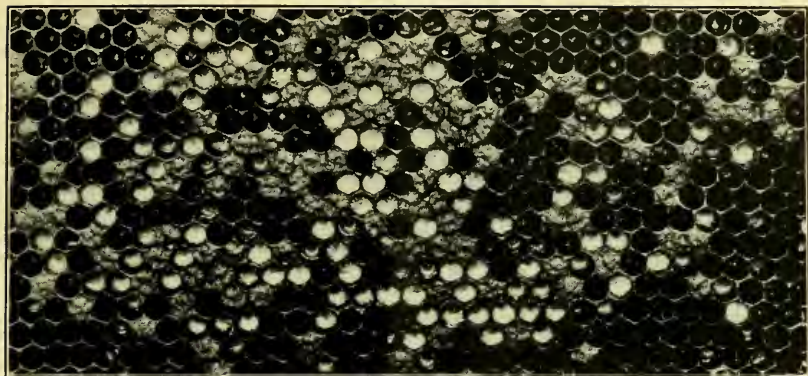
J.—Longisection of larva sick of European foulbrood, showing a later stage of infection than that present in I. The dark area in the food mass shows the bacterial growth. Note that the growth mass does not extend beyond the peritrophic membrane and that it does not extend uniformly along this membrane and throughout the food mass.

K.—Transverse section of larva about the time of its death from European foulbrood infection. Note the bacterial mass along the peritrophic membrane and extending from the membrane into the food mass. As seen within the living larva this bacterial mass in the sick larva is practically white, but is more or less yellowish white when present with larval food material. The gelatinous-like envelope outside the peritrophic membrane and inside the stomach epithelium in healthy larvæ thins out as the disease advances.

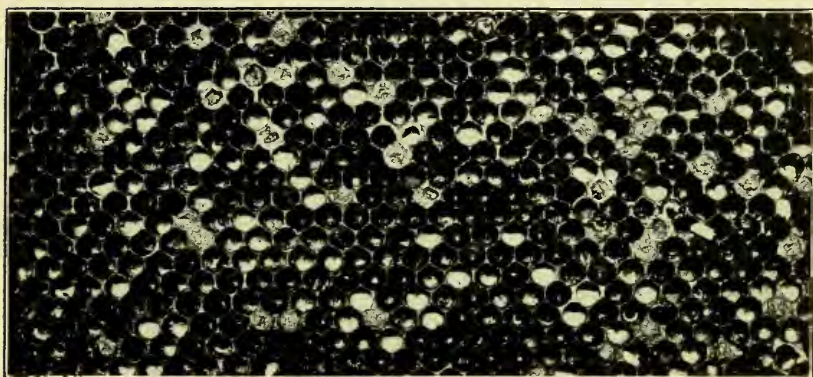
PLATE VIII

The stomach contents of larvæ sick of European foulbrood removed from the organ. The anterior end of the larva is shown. Fairly early stage of infection (a) showing the white bacterial mass broken into fragments as a result of the tension produced in removing the stomach contents from the organ. A somewhat later stage (b) in the course of the disease, showing the bacterial growth contained in the stomach fragmented, also the mucous or gelatinous envelope surrounding the peritrophic membrane. The stomach contents removed from a European foulbrood larva (c) about the time of its death. The bacterial growth at this time is surrounded by very little other than the peritrophic membrane. When this membrane is ruptured the contents flow out as a thin yellowish-white mass.

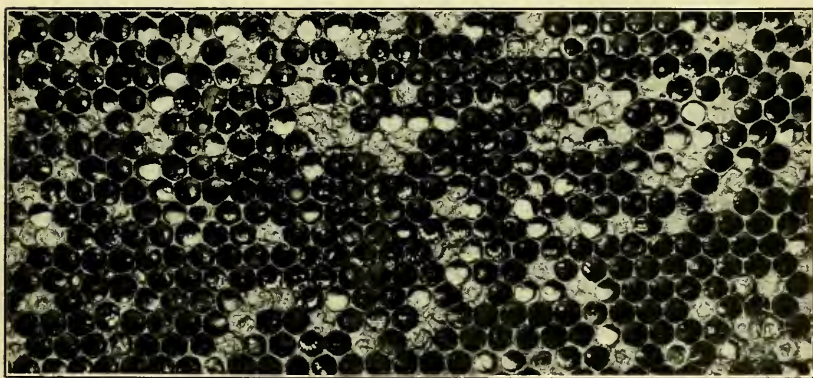




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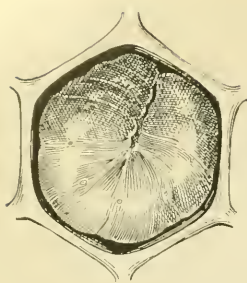


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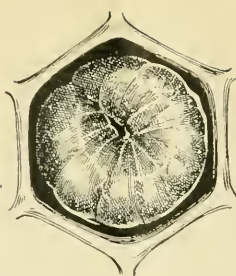


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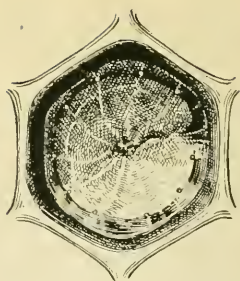
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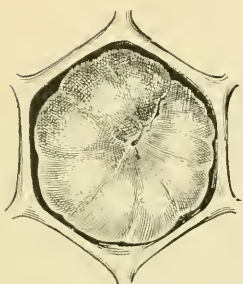
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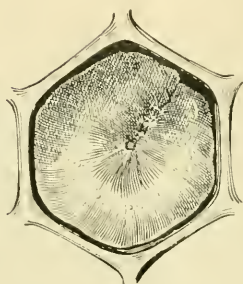
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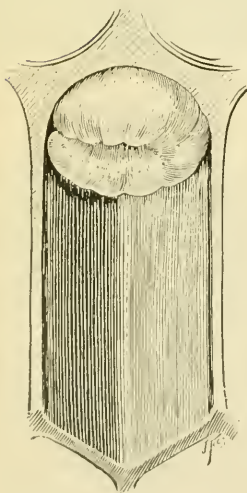
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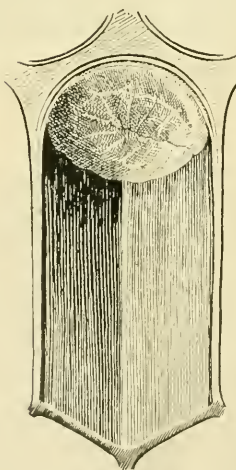
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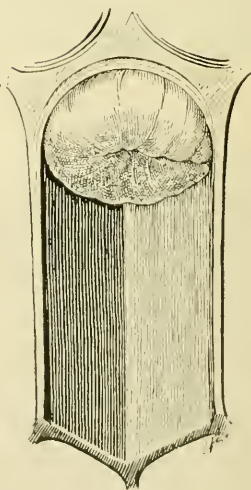
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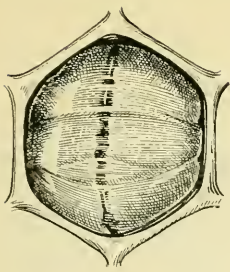


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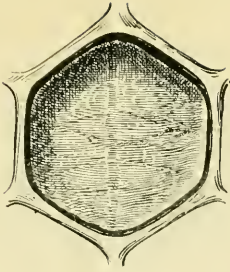


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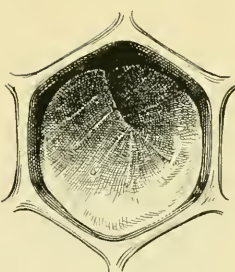
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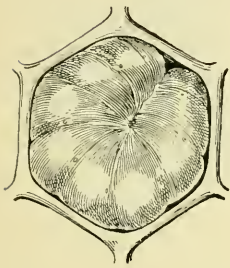
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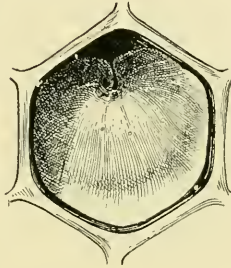
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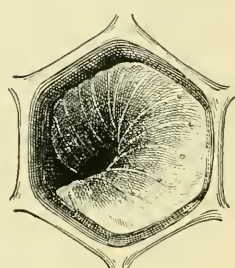
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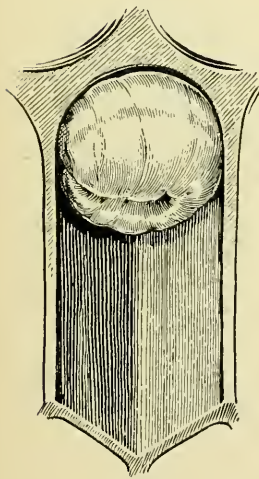
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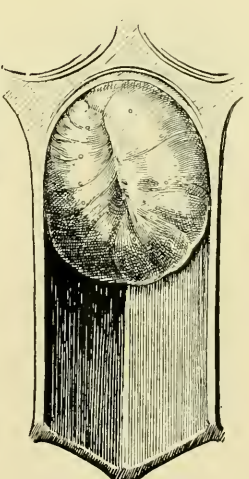
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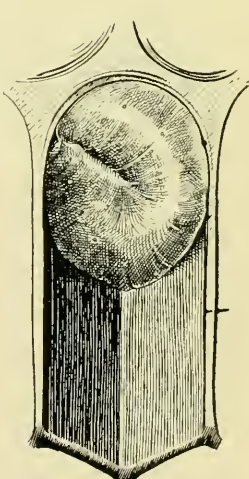
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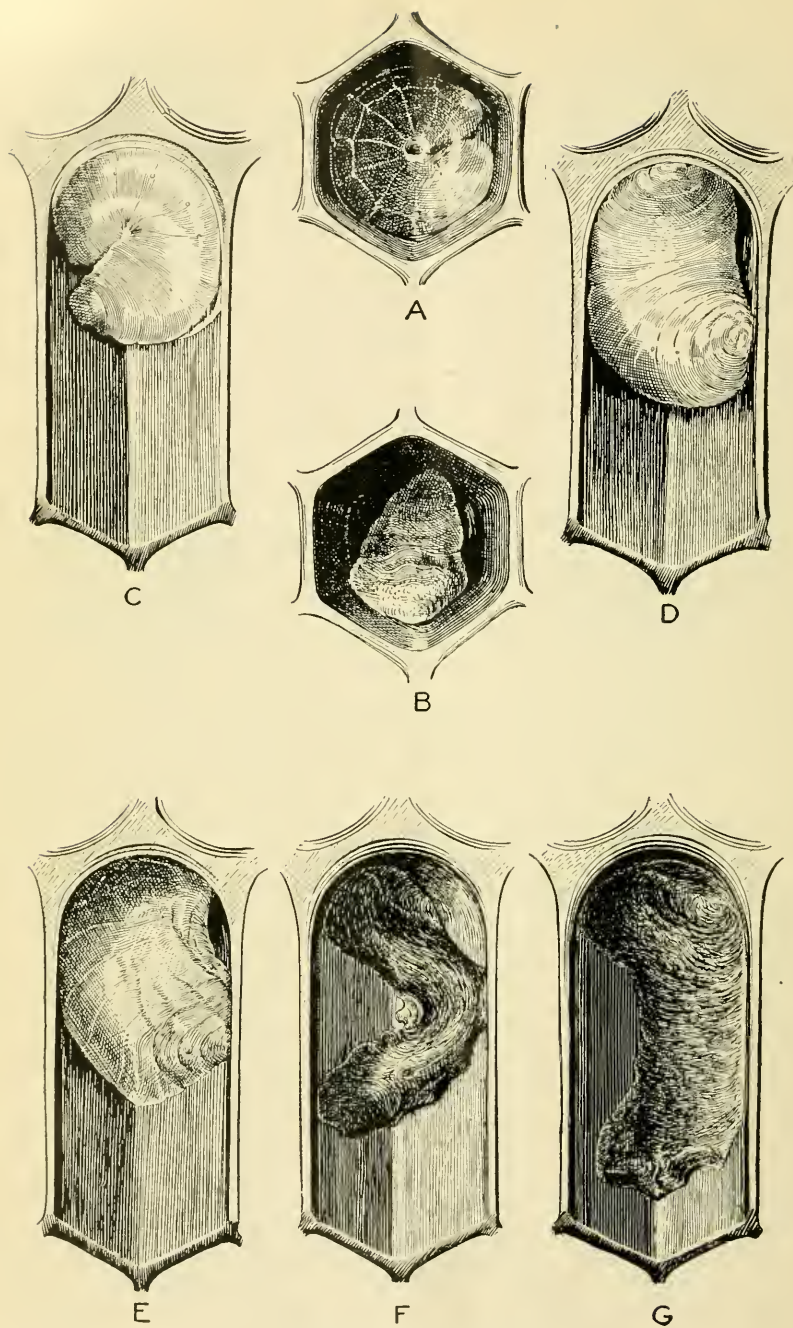


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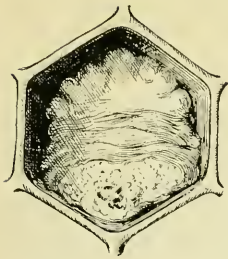


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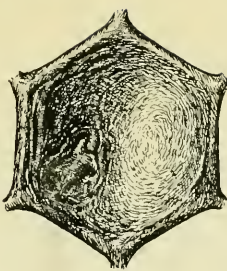
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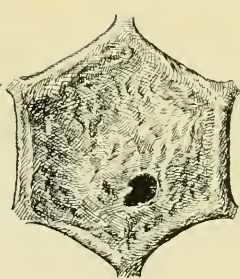
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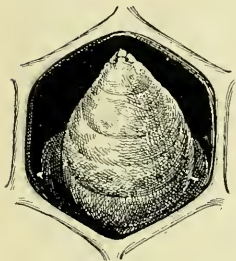
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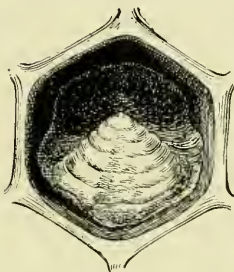
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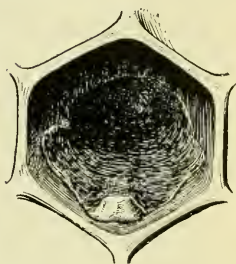
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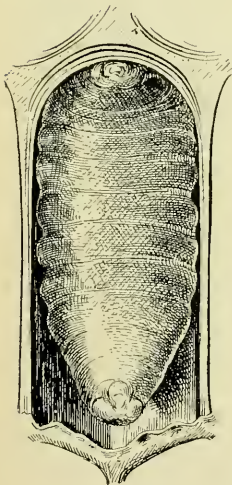
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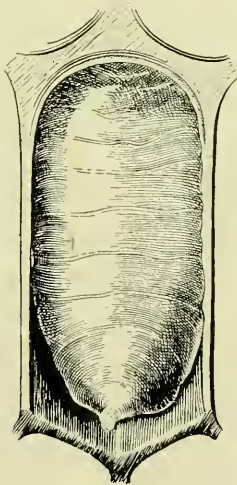
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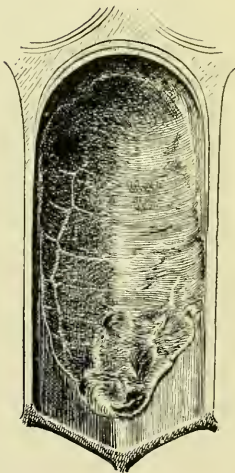
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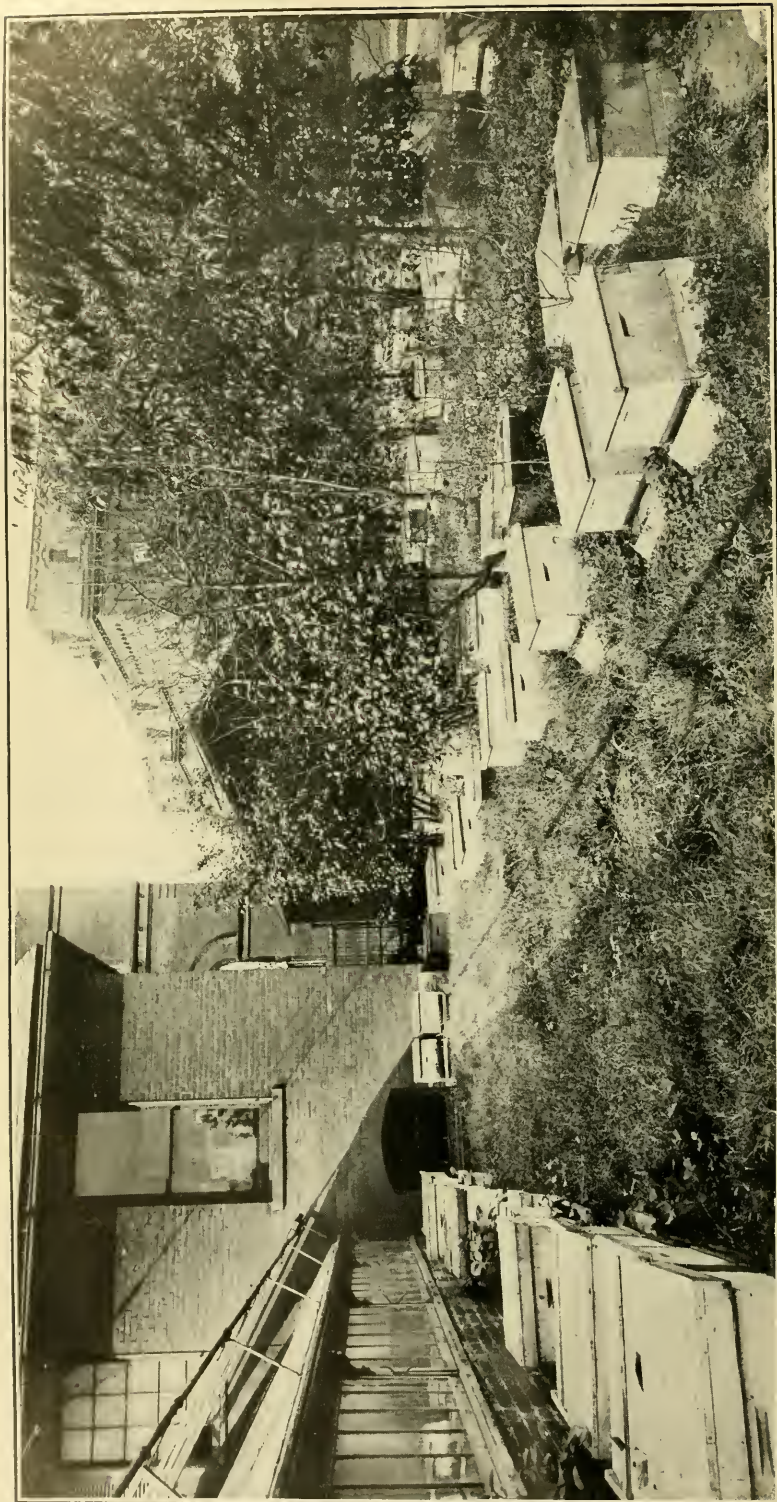


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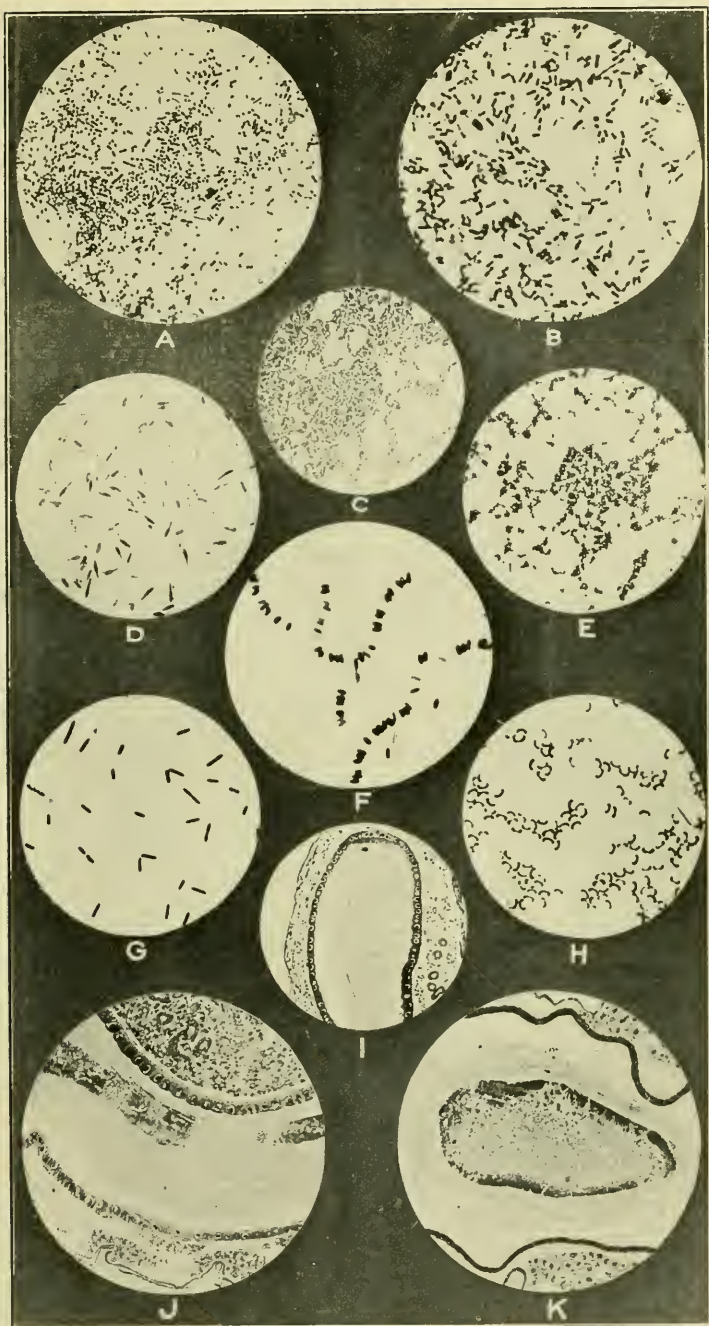


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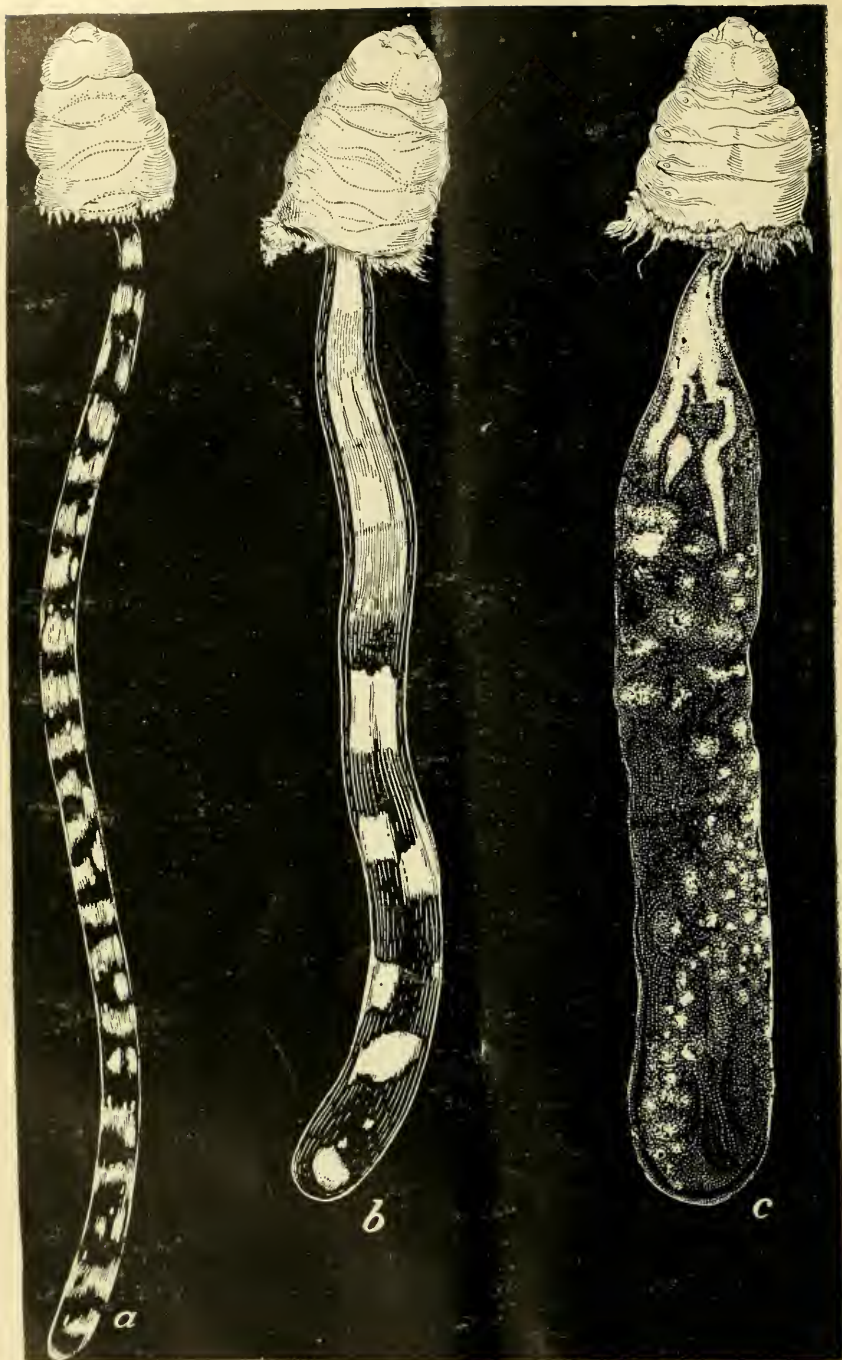
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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 812

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief



Washington, D. C.

PROFESSIONAL PAPER.

May 31, 1920

THE CLOVER AND ALFALFA SEED CHALCIS-FLY.¹

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INTRODUCTION.

The chalcis-fly *Bruchophagus funebris* How. belongs to a group or superfamily of Hymenoptera known as Chalcidoidea. The habits of this species differ considerably from the general habits common to most of the other members of this group. Many of the Chalcidoidea are parasitic Hymenoptera, feeding, in the larval stage, upon various forms of insect life. *B. funebris*, on the other hand, is strictly phytophagous, and feeds within the growing seeds of alfalfa and red clover. This insect has for many years been a pest of clover seed throughout the Middle Western States, and has become generally known as the clover-seed chalcis-fly. The increased production of alfalfa seed throughout the Western States was followed by the rapid development of this insect in nearly all of the alfalfa seed-

¹In the summer of 1912 the writer was detailed to make a study of the alfalfa-seed chalcis-fly (*Bruchophagus funebris* How.), and different phases of these investigations have been continued up to the present time, most of them being conducted in the seed districts of California, Arizona, and Utah. The author's studies of the distribution of this insect and its parasites have been greatly assisted through the kindness of various members of the branch of Cereal and Forage Insect Investigations, and by Mr. Roland McKee, of the Office of Forage Crop Investigations, Bureau of Plant Industry. Special credit is due Messrs. R. N. Wilson, C. N. Ainslie, V. L. Wildermuth, E. G. Kelly, T. H. Parks, and H. T. Osborn, who made many personal field observations in connection with the life-history studies of this insect. The writer is also greatly indebted to Mr. A. B. Gahan for his kindness in making determinations of several new parasites of *B. funebris*.

growing districts of the United States, so that at the present time it is the most destructive pest of alfalfa seed. The injury done is known to many farmers as "blighted seed," but this insect is now becoming more generally known among alfalfa-seed growers as the alfalfa-seed chalcis-fly.

HISTORY AND SYNONYMY.

This species was described by Dr. L. O. Howard¹ as *Eurytoma funebris*. It was for some years supposed to be a parasite of the clover-flower midge, *Dasyneura laguminicola* Lintner. The original description is as follows:

Male.—Length of body 1.7^{mm}, expanse of wings 2.5^{mm}. Head slightly wider than thorax; antennæ nearly as long as thorax; flagellum of antennæ 6-jointed (counting the club as 1 joint); joints very strongly incised from above, subequal in length except club and first joint; each joint, except club, with two whorls of yellowish hair, each whorl as long as the joint. Top of head and thorax coarsely punctured, and covered with sparse and very short whitish hair. Subcostal vein yellowish and strong, reaches costa a little before the middle of the wing, and almost immediately gives off stigma; stigma with a small club and faint indication of a branch. Peduncle very strong and not long; abdomen very small, less than half the length of the thorax. General color black, eyes dark brown, knees, anterior tibiæ, all tarsi light brown.

Female.—Length of body 1.9^{mm}, expanse of wings 2.7^{mm}. Antennæ shorter than in ♂ and joints much more closely united; no hairs; flagellum 7-jointed, the club larger in proportion than in the ♂. Abdomen longer than thorax, not pedunculated; ovipositor slightly extruded, light brown in color.

In 1894 Dr. W. H. Ashmead (2) referred this species to the genus *Bruchophagus*, supposing it to be a parasite of the seed weevils (*Bruchidae*).

Dr. A. D. Hopkins reared specimens from heads of crimson clover in 1896, at first supposing them to be parasites of the clover-seed midge, since they had been referred to as such in early literature. But upon careful examination of the infested seeds he found that *B. funebris* was feeding on the seeds. Dr. Hopkins (3) wrote as follows:

Upon close examination to find their host insect, I was thoroughly surprised to find that it was not a parasite of an insect, but that it bred in the seed, and that scarcely a seed could be found in the bag that had not been a host of one of the interesting little creatures.

Dr. Hopkins (4) again mentions this insect:

Additional evidence obtained from a study of all stages of this insect, together with some observations on its habits, seems to leave no doubt that this interesting little Chalcidid is a destructive enemy of the seed of crimson and common red clover. I also determined that it passes the winter in the seed left in the open field, evidently in the larval stage.

¹ Figures in parentheses refer to "Literature cited," p. 20.

DISTRIBUTION.

In 1904 Dr. E. G. Titus (5) gave the following distribution of *B. funebris* by States: Hanford, Cal.; Fort Collins, Colo.; Marengo and Urbana, Ill.; Winona Lake, Ind.; Richmond, Kans.; Agricultural College, Mich.; Agricultural College, Miss.; St. Anthony Park, Minn.; Quaker Street, N. Y.; Corvallis, Oreg.; Providence, R. I.; Burlington, Vt.; Pullman, Wash.; Danville and Virginia Beach, Va., and the District of Columbia. Mr. George I. Reeves reported this species from Lincoln, Nebr., the same year, and in 1915 Prof. F. M. Webster reported its presence at Tyngsboro, Mass., Kensington, Md., Lebanon, N. H., and Chambersburg, Pa. It was further reported from Wakeman, Ohio, in 1905, by W. B. Hall; at Albuquerque, N. Mex., 1908, Sacaton, Ariz., 1909, and central Utah, 1910, by C. N. Ainslie; at Plano, Tex., in 1909, by T. D. Urbahns; at Twin Falls, Idaho, in 1911, by H. T. Osborn; at Nashville, Tenn., in 1910, by George G. Ainslie; at Newell, S. Dak., in 1913, by C. N. Ainslie; at Alva, Okla., in 1913, by E. G. Kelly; at Charleston, Mo., in 1914, by G. W. Barber; at Minden, Iowa, in 1915, by T. D. Urbahns; at Hagerstown, Md., in 1916, by H. L. Parker; and at Fallon, Nev., in 1917, by T. D. Urbahns.

Under later dates, *B. funebris* was reared from many additional localities by the writer and other persons connected with the Bureau of Entomology, so that at the present time it is known to be present in practically every locality in the United States where either red clover or alfalfa seed is grown to any extent.

In 1913 the writer found it in alfalfa seed reported by a seed dealer to have arrived from Germany. This species has also been reported from other foreign countries as follows:

- 1906, N. E. Hansen, *Medicago falcata*, Omsk, Siberia.
- 1907, C. V. Piper, alfalfa, Turkestan, Asia.
- 1908, Mr. Brand, alfalfa, Pisa and Matilla, Chile.
- 1908, N. E. Hansen, alfalfa, Tashkent, Turkestan, Asia.
- 1908, J. G. Sanders, alfalfa, Tashkent, Turkestan, Asia.
- 1910, C. P. Lounsbury, alfalfa, Cape Town, South Africa.

CHARACTER OF ATTACK.

The injury caused by the chalcis-fly consists entirely of the hollowing out of the developing seeds (Pl. II, fig. 2). By the time the alfalfa seed pods and the clover heads have matured the destructive work of this minute larva has been completed within the infested seed, and the result is a hollow seed containing the insect in one of its stages, or simply the seed shell from which the adult insect has emerged. (Pl. II, figs. 3 and 4.) This pest in no way interferes with the growing of either alfalfa or red clover for forage purposes, except in so far as a very poor stand may be expected when infested and hollowed-out seeds are planted. The loss caused by this pest

is to the growing of alfalfa or clover for a seed crop, and the insect may therefore be considered strictly a seed pest.

FOOD PLANTS.

The following plants have been found to be food plants of the chalcis-fly, *B. funebris*, seeds of each of these having been found infested by this species:

- Alfalfa (*Medicago sativa*).
- Red clover (*Trifolium pratense*).
- Bur clover (*Medicago hispida nigra*).
- Bur clover (*Medicago hispida tercbellum*).
- Bur clover (*Medicago hispida denticulata*).
- Medicago falcata*.
- Medicago ruthemia*.
- Medicago tuncana*.
- Medicago tuberculata*.
- Medicago arabica*.

The seeds of the following list of closely related plants apparently are not attacked by the chalcis-fly:

- White clover (*Trifolium repens*).
- Alsike clover (*Trifolium hybridum*).
- Yellow sweet clover (*Melilotus officinalis*).
- White sweet clover (*Melilotus alba*).
- Sour clover (*Melilotus indica*).

ECONOMIC IMPORTANCE.

Table I shows the destruction of alfalfa and clover seed as found in samples of seed taken in the given localities.

TABLE I.—Percentage of alfalfa and red clover seed found infested by *Bruchophagus funebris*.

Locality.	Date of collection.	Seeds examined.		Seed destroyed.	Remarks.
		Total.	Infested.		
				<i>Per cent.</i>	
Aberdeen, Idaho.	Sept. 19, 1914	886	7	0.7	Alfalfa seed.
Do.	do.	902	45	5	Do.
Albany, Oreg.	Sept. 5, 1914	156	81	52	Red clover seed.
Bard, Calif.	May 7, 1915	1,374	723	52.6	Alfalfa seed.
Do.	May 12, 1915	1,000	361	36.1	Do.
Do.	May 20, 1915	1,100	260	23.6	Do.
Do.	May 28, 1915	1,053	222	21	Do.
Do.	June 8, 1915	1,236	400	32.3	Do.
Do.	June 17, 1915	1,091	291	26.5	Do.
Do.	June 23, 1915	1,005	268	26.6	Do.
Do.	July 2, 1915	1,115	315	28.2	Do.
Do.	do.	1,228	311	25.3	Do.
Do.	July 28, 1915	1,255	672	54.4	Do.
Do.	Aug. 4, 1915	1,364	489	36	Do.
Do.	do.	1,125	245	21.7	Do.
Do.	Aug. 8, 1915	1,028	533	48.1	Do.
Do.	do.	1,157	330	28	Do.
Do.	Oct. 12, 1915	872	747	85	Do.
Bishop, Calif.	Nov. 10, 1914	691	212	30.7	Do.
Buckeye, Ariz.	Sept. 2, 1912	263	217	82	Do.
Burley, Idaho	Sept. 11, 1914	1,307	50	3.8	Do.
Caldwell, Idaho	Sept. 10, 1914	866	237	27.3	Do.
Chico, Calif.	Apr. 12, 1912	3,007	1,761	58.5	Do.
Do.	Oct. 25, 1914	263	83	31	Do.
Chino, Calif.	Sept. 24, 1912	574	195	34	Do.

TABLE I.—Percentage of alfalfa and red clover seed found infested by *Bruchophagus funebris*—Continued.

Locality.	Date of collection.	Seeds examined.		Seed destroyed.	Remarks.
		Total.	Infested.		
				<i>Per cent.</i>	
Columbus, Ohio.....	Oct. 17, 1908	559	50	8.9	Red clover. ¹
Corcoran, Calif.....	Oct. 3, 1912	317	118	37	Alfalfa seed.
Dos Palos, Calif.....	Sept. 15, 1913	993	264	26.5	Do.
Glendale, Calif.....	Aug. 26, 1912	311	32	12	Do.
Do.....	Jan. 12, 1914	603	145	24	Do.
Gunnison, Utah.....	Sept. 23, 1914	816	34	4	Do.
Do.....	do.....	876	105	12	Do.
Do.....	do.....	835	59	7	Do.
Do.....	do.....	297	11	3.7	Do.
Do.....	do.....	591	35	5.9	Do.
Logan, Utah.....	Dec. 28, 1915	1,527	680	44.5	Do. ²
Manti, Utah.....	Sept. 23, 1914	1,097	92	8.4	Do.
Mesilla Park, N. Mex.....	Aug. 30, 1908	561	130	30.5	Do. ³
Do.....	do.....	531	170	47.1	Do.
Murrietta, Calif.....	Aug. 7, 1915	1,140	177	15.6	Do.
Myton, Utah.....	Apr. 5, 1912	1,000	395	39.5	Do. ⁴
Nephi, Utah.....	Sept. 24, 1914	994	35	3.5	Do.
Do.....	do.....	845	119	13.5	Do.
Do.....	do.....	700	131	18.5	Do.
Do.....	do.....	1,046	19	1.8	Do.
Do.....	do.....	935	23	2.4	Do.
Pendleton, Oreg.....	Sept. 9, 1914	764	229	30	Do.
Red Bluff, Calif.....	Sept. 3, 1914	966	147	15.2	Do.
Riverside, Calif.....	do.....	492	109	22	Do.
St. Anthony, Idaho.....	Sept. 17, 1914	629	23	3.6	Do.
Salt Lake City, Utah.....	May —, 1910	100	37	37	Do. ³
Do.....	do.....	400	149	62.8	Do. ³
Do.....	do.....	500	186	37.2	Do. ³
Do.....	Oct. 17, 1910	500	286	57	Do. ³
Do.....	Nov. 22, 1910	107	77	72	Do. ³
Do.....	Sept. 20, 1911	450	5	1	Clover. ⁴
Do.....	Jan. 16, 1914	1,387	52	3.7	Alfalfa seed.
Somerton, Ariz.....	May 10, 1915	1,235	664	53.8	Do.
Tempe, Ariz.....	June 28, 1912	167	-----	-----	Do. ⁵
Do.....	July 1, 1912	348	-----	-----	Do. ⁵
Do.....	July 8, 1912	670	237	35.4	Do.
Do.....	July 15, 1912	684	403	50	Do.
Do.....	Aug. 10, 1912	301	235	78	Do.
Do.....	Oct. 29, 1912	321	134	42	Do.
Do.....	July 22, 1913	899	412	46	Do.
Do.....	do.....	2,270	778	35	Do.
Do.....	Aug. 20, 1913	939	439	47	Do.
Do.....	July 24, 1914	1,445	408	28	Do.
Do.....	Aug. 15, 1914	1,185	212	18	Do.
Twin Falls, Idaho.....	Sept. 14, 1914	1,117	322	29	Do.
Tulare, Calif.....	Oct. 1, 1912	600	154	25.5	Do.
Do.....	Nov. 18, 1913	655	243	37.5	Do.
Washington, D. C.....	Oct. 20, 1910	361	96	26	Clover. ¹
Wellington, Kans.....	June 3, 1910	400	333	83	Alfalfa seed. ⁶
Do.....	June 6, 1910	600	480	80	Do.
Woodland, Calif.....	Sept. 2, 1914	558	98	18	Do.
Yuma, Ariz.....	Aug. 6, 1913	1,143	109	9.5	Do.
Do.....	Aug. 7, 1913	833	277	24.4	Do.
Do.....	do.....	2,174	524	24	Do.
Do.....	Oct. —, 1913	915	646	72.5	Do.
Do.....	Dec. 19, 1913	484	443	91	Do.
Do.....	Dec. 22, 1913	1,377	1,017	74	Do.
Do.....	June 18, 1914	335	76	22.7	Do.
Do.....	do.....	1,076	171	16	Do.
Do.....	do.....	391	82	21	Do.
Do.....	do.....	585	24	4.2	Do.
Do.....	do.....	554	95	17	Do.
Do.....	Apr. 24, 1915	706	277	39.2	Do.
Do.....	June 11, 1915	1,047	311	29.5	Do.
Do.....	July 21, 1915	1,295	214	16.5	Do.
Do.....	do.....	1,106	211	19.1	Do.

¹ Note made by T. H. Parks.² Note made by E. L. Barrett.³ Note made by C. N. Ainslie.⁴ Note made by H. T. Osborn.⁵ Note made by R. N. Wilson.⁶ Note made by E. G. Kelly.

The loss to the alfalfa-seed crop depends upon the total yield and upon the percentage of infestation.

This loss frequently varies from 50 to 400 pounds per acre as a result of the destructive work of this pest. At an average price of 12 cents per pound the loss may then be estimated at from \$6 to \$48 per acre annually. While this loss in the aggregate is enormous, there is frequently an additional loss which is caused by the planting of uncleaned seed, resulting in a poor stand and the loss of time and money in replanting.

COMMON NAMES.

Bruchophagus funebris is commonly known throughout the Eastern States as the clover-seed chalcis-fly. Throughout the alfalfa seed-growing districts, which are located almost entirely in the Western States, this insect is better known as the alfalfa-seed chalcis fly. Many farmers, however, frequently refer to its destructive work as that of a seed weevil, while others simply refer to the injured seed as "blighted seed," and apparently are not familiar with the cause of this condition.

MEANS OF DISPERSION.

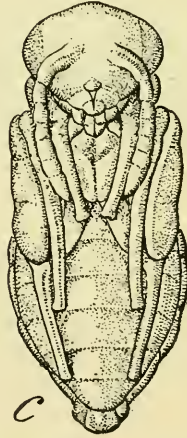
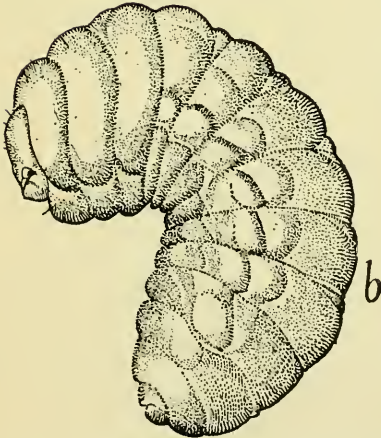
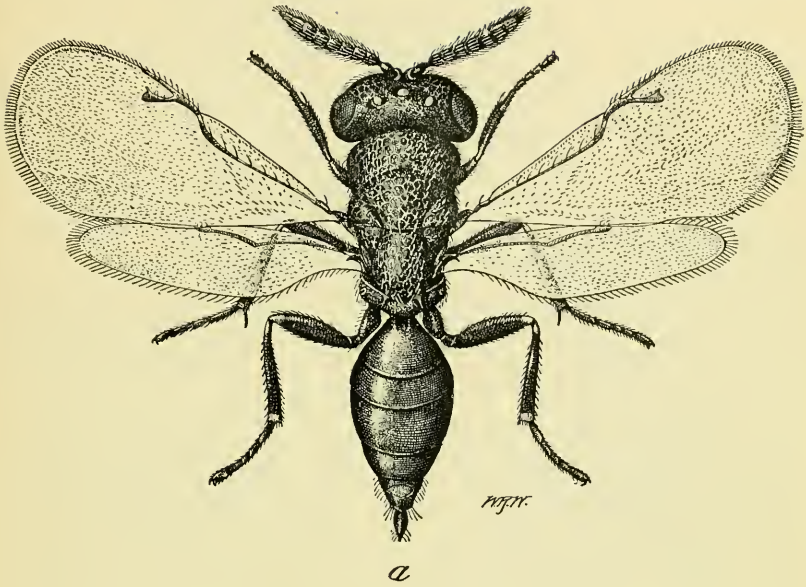
At the present time it is impossible to study in detail the means by which *B. funebris* became distributed over the different parts of the United States, for the reason that it is now found in almost every locality where either alfalfa or red-clover seeds are grown to any extent. It is, in fact, very probable that this species is a native of this country.

The shipment of infested seed from one locality to another has, without doubt, been a great factor in the dispersion of the alfalfa-seed chalcis-fly, since one can visit seed houses and frequently find hundreds of the adults present in the sacks of either clover or alfalfa seed.

Their spread probably was greatly aided also by the early settlers, who traveled across the country with horses and wagons, taking with them either clover or alfalfa hay bearing a few infested seed pods.

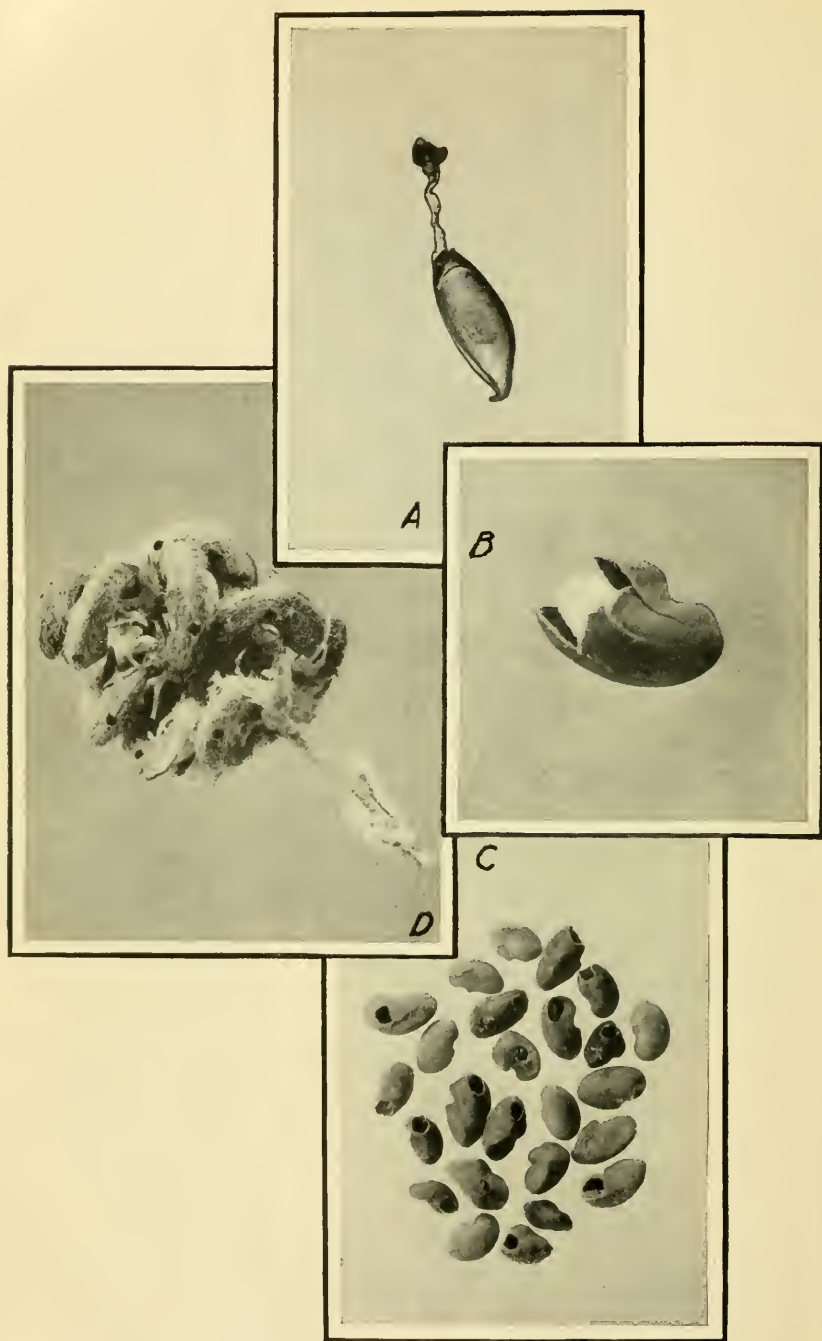
Throughout the mountain States there frequently is found a chain of small alfalfa patches along the mountain streams connecting the larger irrigation valleys, where alfalfa plants, along the edges of these fields, develop seed pods, and render conditions favorable for the spread of this insect from one field to another. Infested seeds and pods are undoubtedly washed down the mountain streams, enter irrigation canals, and may become distributed with the water over new fields many miles away.

The wind is an important factor in the dispersion of the adults of *B. funebris* over adjoining fields. The writer has frequently observed large numbers of chalcis-flies being carried by the strong summer breeze from one field to another. On one occasion more than



THE CLOVER AND ALFALFA SEED CHALCIS-FLY (*BRUCHOPHAGUS FUNEBRIS*).

a, Adult; *b*, larva; *c*, pupa.



THE CLOVER AND ALFALFA SEED CHALCIS-FLY.

A, Egg; B, larva in hollow seed; C, cluster of seed pods showing openings from which adults emerged;
D, seeds hollowed by *Bruchophagus fovealis*.

two hundred adults of *B. funebris*, carried by the wind from a near-by field, alighted upon the writer's shirt in the course of a few minutes. Further observations revealed thousands of these chalcis-flies being carried by the winds.

LIFE HISTORY.

METHOD OF STUDY.

The life history of this seed chalcis-fly was studied by selecting old alfalfa plants and first carefully removing all seed pods which had begun to develop. The fresh blossoms were then artificially pollenized and covered with thin cheesecloth bags. About one week later the bags were removed and a mica breeding cage was placed over the soft green seed pods. One or more adults of *B. funebris* were then placed in the cage for oviposition into the green seeds. The mica cage, with the adults of *B. funebris*, was usually removed after one day, and the seed pods were again covered with cheesecloth bags. Here they were allowed to remain until desired for dissection and study of the various stages of the chalcis-fly, or until the first adults emerged. It was found that larvæ of *B. funebris*, which had been removed from their natural cavities in the infested seed, could be transferred to a cavity made in a small cork, and if properly covered with a medical capsule, or a small glass vial, they could be reared to the adult stage without difficulty in the laboratory. The hibernating larvæ and pupæ also were carried successfully through to the adult stage in cavities made between two layers of sheet cork.

Examinations of matured seeds were made by soaking the seeds for a few hours and then dissecting them under a binocular microscope.

The period of incubation was studied by allowing adults to oviposit into seed pods covered with mica cages and then dissecting some of the seed from day to day until the first eggs were found to have hatched.

THE EGG.

The egg (Pl. II, A) of *B. funebris* is small, elongated, measuring about 0.2 mm. long and 0.08 mm. in thickness. It consists of a delicate membranous bag filled with a semiliquid substance. One end of the egg is terminated in a flexible point, while the opposite end is marked by a slender tube-like film measuring about 0.2 mm. in length.

LARVA.

The larva (Pl. I, B) is grublike in shape. It averages 1.9 mm. long and 0.9 mm. wide when fully developed. The pointed brown mandibles are chitinous and visible to the unaided eye. With the exception of the mandibles the larva is white. It has no feet or legs

and is almost free from pubescence. The 13 body segments are at times quite prominent.

PUPA.

The pupa (Pl. I, C) measures 1.8 mm. long. It is at first white, later the eyes and ocelli are brown, and before becoming adult the pupa turns black. All appendages are folded close to the body, and a thin pupal skin covers the insect in this stage of its development.

ADULT.

The adult (Pl. I, A) of *B. funebris* is a very small black insect measuring about 2 mm. in length. Frequently thousands are seen flying over the horses and mower when the alfalfa seed crop is being harvested. They also collect in great swarms on the shady sides of alfalfa seed stacks, from which these insects emerge. Farmers frequently mistake the adults of this species for gnats, which are about the same size and are frequently very troublesome at the time when the chalcis-fly is most abundant.

SEASONAL HISTORY.

EARLY DEVELOPMENT.

The first development of the chalcis-fly may be found in February and March throughout the Southwest, when the hibernating larvæ begin to transform to the pupal stage. Spring temperatures and moisture conditions determine the time of this transformation. In colder climates it is much later, and under desert conditions the larval stage may be prolonged indefinitely.

FIRST APPEARANCE OF ADULTS.

The first adults appear in the spring, about four or five weeks after warm weather has set in. It is probable that in southern California adults may be active in small numbers throughout the entire winter. Adults of *B. funebris* were taken in the fields in the San Fernando Valley, Calif., as early as March 3, but they usually do not appear in large numbers until about April. At Yuma, Ariz., they make their appearance in March, and the first seed pods, which usually develop along the check ridges, become infested by the middle of April. On April 17 green pods were taken at the edge of a field at Yuma, and upon careful examination, 8 seeds showed very small larvæ, 5 showed half-grown larvæ, 15 showed full-grown larvæ, and 20 showed *B. funebris* pupæ. E. G. Kelly observed adults of *B. funebris* in the field at Wellington, Kans., as early as April 21. H. T. Osborn reared them in out-of-door breeding cages in the same locality as early as April 17. In the valleys of central California the adults of *B. funebris* become active in April and oviposit into the seed pods of bur clover (*Medicago hispida*), which forms seed pods much earlier than alfalfa.

Mr. Kelly reported adults of *B. funebris* active and ovipositing in alfalfa seed pods at Wellington, Kans., by June 10, 1911.

OVIPOSITION.

The adults of *Bruchophagus funebris* appearing in early spring are not always able to locate developing seeds of their host plants at the time of their emergence, and it may be three or four weeks before an opportunity for oviposition is found. In midsummer oviposition takes place within a few days after the adult emerges. Green and half-grown seed pods are favored for oviposition. The female adult takes a position directly over the slight enlargement on the pod caused by the developing seed. The ovipositor is forced through the green seed pod and into the soft watery seed, where the egg is placed. The time required for oviposition is about one minute.

POSITION OF EGG.

The egg is usually placed just beneath the inner integument of the seed, sometimes between the cotyledons, and frequently within the semiliquid contents of a cotyledon. It is placed singly, although oviposition into the same seed may be repeated. The mark left by oviposition may sometimes be seen in the form of a very minute spot on the surface of the seed, but this is usually not discernible even with the aid of a microscope. The relative position of the seeds in a pod in no way seems to influence the chances of infestation.

EGG STAGE.

Observations made during the month of April at Pasadena, Calif., showed the period of incubation as requiring from 7 to 12 days. In the month of June the incubation period was found to be about five days. E. L. Barrett, assisting the writer, found eggs of *B. funebris* hatching in four days during very warm weather.

LARVAL STAGE.

The larva, upon hatching from the egg, finds itself surrounded with the soft contents of the growing seed. The first feeding takes place after the larva is one or two days old, and in midsummer rapid growth follows. The larva of *B. funebris* never leaves the seed in which it is developing to infest another seed in the same pod. Where two or more larvæ chance to be in the same seed, one or both usually perish before development is completed. Molts, apparently, occur indefinitely in the larval stage, and appear to be the peeling off, in small fragments, of the old larval skin. The

time required for the complete development of the larval stage varies under differing temperature conditions, and depends upon the condition of the seed in which it develops. Under the most favorable conditions, as observed by the writer, the larvæ completed development in 12 days. In early spring this period was prolonged to 30 days.

PERIOD OF AESTIVATION.

The factors of greatest influence in the life cycle of *B. funebris* are those which determine the period of aestivation. Larvæ of this species, reaching their full larval development in soft green seeds, at once transform to the pupal stage and soon emerge as adults. On the other hand, if the infested seeds mature and harden before the larval development is fully completed aestivation follows. This resting period frequently continues throughout the remainder of the season, or until conditions become favorable for pupation and transformation to the adult stage.

Atmospheric humidity, temperature, and irrigation are important factors determining the duration of aestivation. Aestivation occurs frequently in the larvæ of *B. funebris* during the months of July, August, and September. Favorable conditions may at any time cause transformation to the pupal stage or aestivation may continue into hibernation. The transformation usually occurs at any time between March and July of the following season, though in exceptional cases the larval stage may be continued into the second year.

Alfalfa seeds collected in the fields on September 24, 1912, and kept dry in the laboratory showed adults of *B. funebris* emerging throughout the season of 1913 and larvæ living in the seeds until the spring of 1914. The last adults of *B. funebris* emerged as late as September, 1914. This habit causes great diffusion in the adults of the species. It was found that some of the progeny of a single adult developed and reached maturity in about 30 days, while other progeny from the same adult and from eggs deposited on the same day did not mature until the next year.

PUPATION.

The period of pupation in early spring requires an average of about 30 days, as shown by Table II. As the season advances and the days become warmer the duration of the pupal period is much shortened. Pupæ developing in midsummer have a pupal period of from 6 to 10 days, and under the most favorable conditions this period is without doubt shorter than that observed in the breeding cages.

LATE APPEARANCE OF ADULTS.

While some of the larvæ apparently go into hibernation as early as August, adults may be seen emerging from the infested seeds and seed pods in the months of October and November.

At Glendale, Calif., adults were still active in the fields as late as November 18, in 1912. C. N. Ainslie reported *B. funebris* as being numerous among the florets of red clover on September 17, in 1913, at Fairmont, Minn. At Albany, Oreg., the writer found them active over red clover on September 15, in 1914. At Nephi, Utah, they were active on alfalfa florets on September 24 of the same year. Activity of the adults, oviposition, and development of larvæ usually continue as long as green seed pods are present in the fields. The first heavy frost kills the adults and pupæ and most of the undeveloped larvæ.

The writer's observations show that in southwestern Arizona this species may have as many as four generations in a single season. This is, of course, under favorable conditions—first on volunteer alfalfa and then in the irrigated seed fields. Without doubt it completes at least two generations in most of the intermountain seed-growing districts, where the growing seasons are frequently very short. The minimum number of generations in a single season may be less than one under very unfavorable conditions, as it required more than one season for some of the individuals under observation to reach the adult stage.

TABLE II.—Length of the pupal period for 50 individuals of *Bruchophagus funebris* which hibernated in the larval stage.

Pupal period of male.		Pupal period of female.	
	Days.		Days.
Mar. 10 to Apr. 14.....	35	Mar. 10 to Apr. 22.....	43
Mar. 11 to Apr. 22.....	42	Mar. 10 to Apr. 14.....	35
Mar. 10 to Apr. 21.....	42	Mar. 11 to Apr. 14.....	34
Feb. 19 to Apr. 12.....	52	Mar. 10 to Apr. 22.....	43
Mar. 10 to Apr. 22.....	33	Mar. 11 to Apr. 22.....	42
Mar. 14 to Apr. 6.....	23	Mar. 11 to Apr. 21.....	41
Mar. 17 to Apr. 16.....	30	Mar. 20 to Apr. 28.....	39
Mar. 11 to Apr. 2.....	22	Mar. 11 to Apr. 14.....	34
Mar. 11 to Apr. 4.....	24	Mar. 21 to Apr. 24.....	34
Mar. 14 to Apr. 6.....	23	Mar. 10 to Apr. 14.....	35
Mar. 14 to Apr. 10.....	27	Mar. 17 to Apr. 22.....	36
Mar. 14 to Apr. 11.....	28	Mar. 10 to Apr. 14.....	35
Mar. 23 to Apr. 25.....	23	Mar. 10 to Apr. 14.....	35
Mar. 18 to Apr. 19.....	32	Mar. 10 to Apr. 22.....	43
Mar. 11 to Apr. 1.....	21	Mar. 14 to Apr. 13.....	30
Mar. 11 to Apr. 4.....	24	Mar. 16 to Apr. 13.....	28
Mar. 11 to Apr. 4.....	24	Mar. 18 to Apr. 18.....	31
Mar. 16 to Apr. 13.....	28	Mar. 18 to Apr. 19.....	32
Mar. 14 to Apr. 4.....	21	Mar. 12 to Apr. 21.....	40
Mar. 17 to Apr. 15.....	29	Mar. 11 to Apr. 6.....	26
Mar. 13 to Apr. 10.....	28	Mar. 14 to Apr. 11.....	28
Mar. 18 to Apr. 14.....	27	Mar. 14 to Apr. 15.....	32
Mar. 11 to Apr. 2.....	22	Mar. 14 to Apr. 11.....	28
Mar. 11 to Apr. 6.....	26	Mar. 13 to Apr. 15.....	33
Mar. 11 to Apr. 2.....	22	Mar. 11 to Apr. 6.....	26
Average.....	28.3	Average.....	34.5

HIBERNATION.

B. funebris hibernates in the larval stage within the infested seed, and the first larvæ enter hibernation as early as August. In fact, many larvæ, after spending a part of the summer in aestivating, continue into hibernation without resuming apparent activity. On the other hand, large numbers of larvæ of this species can be found active in the seeds throughout September and October, and a few of them have been found feeding in the green alfalfa seeds throughout the month of December and even until they were killed by heavy frosts in early January. Early spring rains, together with warm days, mark the end of hibernation for a large percentage of the larvæ.

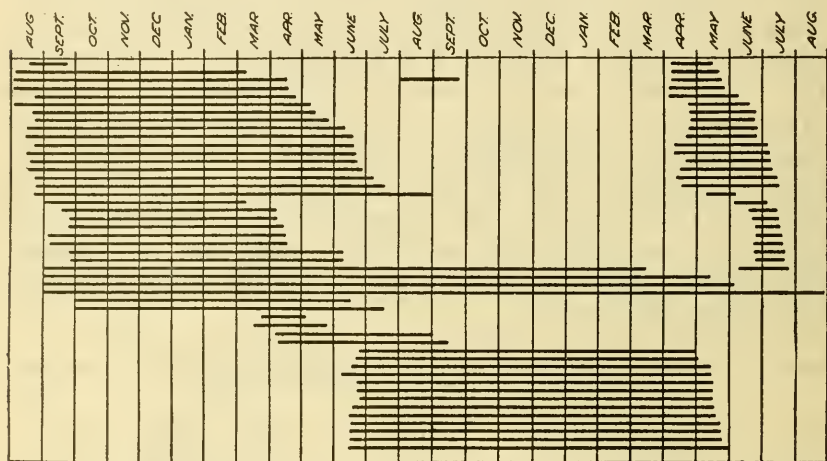


FIG. 1.—Diagram showing development of *Bruchophagus funebris*. Each heavy line shows the time required for one individual from the egg to the adult stage.

In southern California the first pupæ may be found in the latter part of February, and these increase in great numbers throughout the month of March. H. T. Osborn, formerly of the Bureau of Entomology, reported *B. funebris* entering the pupal stage at Wellington, Kans., during the month of March under conditions slightly unfavorable to pupation. Some of the individuals continue to rest in the larval stage until late in the spring, and frequently until mid-summer. The greatest number of hibernating larvæ are found along the edges of the field, along fence lines, and in neglected seed fields. In fact, they may be found wherever large numbers of infested seeds have been allowed to remain on the fields unharvested.

In figure 1 each heavy line shows the time required for the development of a single individual of *B. funebris*. The different lengths of these lines show the period of development from the egg

to the adult stage to be from 26 days to 24 months, and, in a few cases, to carry the individuals through two winters before the adult stage is reached.

RELATIVE INFESTATION THROUGHOUT THE SEASON.

During the season of 1915 newly formed alfalfa seed pods were taken at Bard, Calif., at intervals of about one week, and examined for infestation by the seed chalcis-fly. It was found that the seed pods taken as early as April 24 showed 39 per cent of the seeds to be infested. On May 8, as many as 52 per cent showed infestation by the chalcis-fly. This was undoubtedly due to the increased emergence of the chalcis-fly. The period from the middle of May to the middle of July, at which time the pods were forming in great

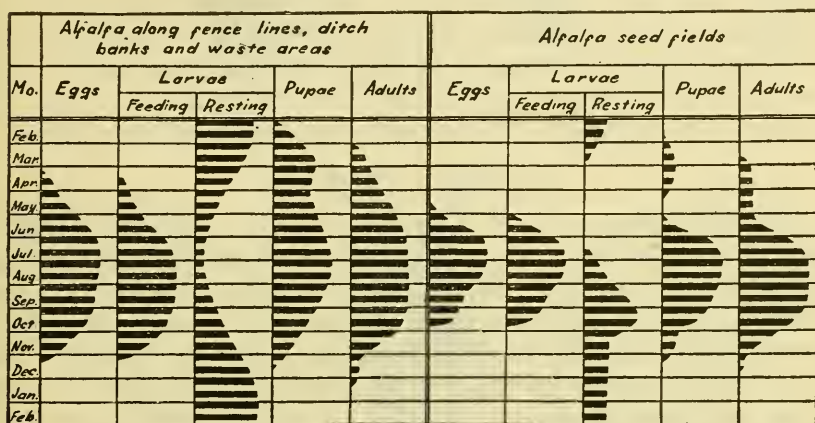


FIG. 2.—Diagram showing comparative abundance of the stages of *Bruchophagus funebris* during the different months of the year.

abundance, showed the infestation dropping to an average of 28 per cent.

The average infestation for the period from the middle of July to the end of September increased to 49.5 per cent. This was undoubtedly due to the increased number of the chalcis-flies and to the rapid decrease in the seed pods caused by the cutting of alfalfa on many of the seed fields.

By October all the seed fields had been harvested, and the chalcis-flies were forced to breed in the green pods still forming along the edges of the fields. Seed pods collected on October 12 showed 85 per cent of the seeds to be infested.

Figure 2 shows the comparative abundance of the stages of *B. funebris* during the different months of the year.

It will be noted by the chart that eggs of *B. funebris* are found earlier along fence lines than in the seed field. This is due to the

fact that isolated plants on waste areas form the earliest pods, and the seed fields are cut for hay before the seed crop is grown. A sudden scarcity of eggs, feeding larvæ, and pupæ is seen in the field in October, which is due to the harvesting of the latest seed crops. Resting larvæ continue to remain on the field throughout the winter in remaining seed pods, but are much more abundant along fence lines. Spring irrigation of seed fields hastens emergence of adults, and this results in the absence of resting larvæ and pupæ on most fields during the month of May.

PARTHENOGENESIS.

The parthenogenetic habit is well established in the females of this species. Female adults, reared from pupæ which were completely isolated, were placed in cages for oviposition into green alfalfa seed pods. All precautions were taken against earlier infestation of the green seeds. These virgin females oviposited freely, and their progeny was reared in breeding cages. The largest number of offspring from a single female observed by the writer was 20, and all of the progeny of these virgin females proved to be males.

CONTROL METHODS.

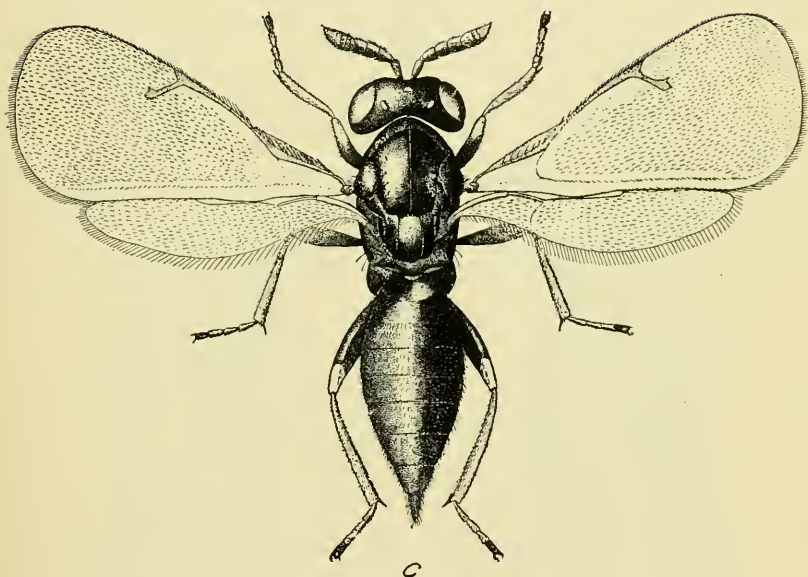
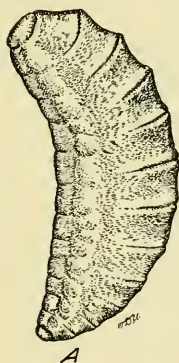
The practical methods of controlling the chalcis-fly in the alfalfa and clover seed fields are mostly cultural methods. It can not be hoped to eradicate this pest from any seed-producing locality; but with the proper methods effectively applied thousands of dollars can be saved annually to the different seed-growing districts. Because of the rapid dispersion of the adults of this species it is of vital importance that control methods should be taken up by community action rather than by the individual.

BURNING OVER OF FENCE LINES.

Everywhere in the alfalfa and red clover seed-growing districts one will find large quantities of standing plants along the fence lines and waste areas bearing the seeds infested by hibernating larvæ. Many hibernating larvæ of the chalcis-fly can be destroyed in the fall of the year by burning over such areas, thereby greatly lessening the abundant emergence of adults in early spring. It has been found that live stock can not be depended upon to rid the fence lines of standing alfalfa in the winter unless there is a great shortage of forage.

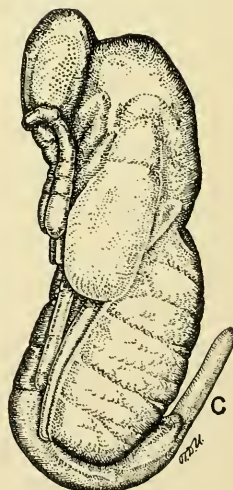
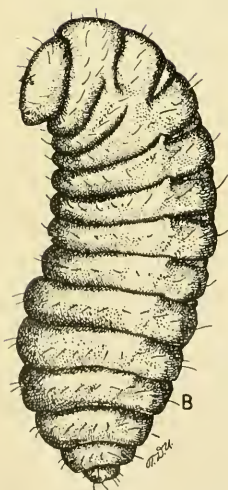
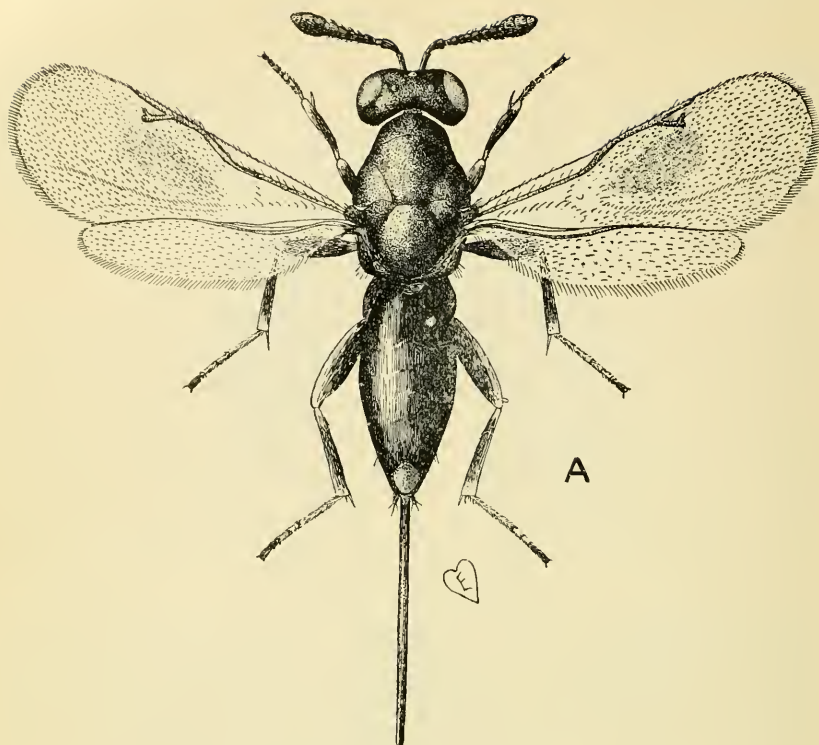
WINTER CULTIVATION.

The cultivation of alfalfa seed fields during the winter is of much value in covering the infested alfalfa seeds containing hibernating larvæ. It is not necessary that infested seeds should be covered to



TETRASTICHUS BRUCHOPHAGI.

A, Larva; B, pupa; C, adult.



LIODONTOMERUS SECUNDUS.

A, Adult female; B, larva; C, pupa.

such a depth that the emerging adults are unable to reach the surface, because the slightest covering of moist soil will cause many of the infested seeds to mold, and prevent development of the pupal or adult stages.

The necessary cultivation can be accomplished by the use of an alfalfa cultivator, spring-tooth harrow, or a disk. Care should be taken that the surface of the field is left smooth, to facilitate close cutting, as well as to prevent clods and gravel from being taken up with the seed when the seed crop is harvested.

IRRIGATION OF ALFALFA SEED FIELDS.

Whenever possible, the alfalfa seed grower should do most of his irrigating in early spring, or before the seed crop is grown. Where this can be practiced, two important points may be gained. First, the tender, rank growth of alfalfa usually following irrigation will be removed as an early fodder crop, and a steady growth of more substantial stems will take its place to produce the seed crop. Second, irrigation of a seed field stimulates the emergence of the chalcis-flies which remain within the infested seeds upon the ground. The humidity of the atmosphere over an irrigated field accelerates the emergence of this pest from seeds of the newly forming crop, which would otherwise become sufficiently dry to force many of the larvæ into a resting period.

It has been supposed by farmers that flooding the seed fields after the first crop of alfalfa has been removed would destroy the larvæ of the chalcis-fly present in alfalfa seeds upon the ground. The writer has found that soaking infested seed in water for four or five days is not sufficient to kill the larvæ resting within the seeds. This would render any attempt at their destruction by irrigation impractical.

CUTTING EARLY PLANTS ON WASTE AREAS.

The fence lines, ditch banks, and other waste areas where volunteer alfalfa can be found, are among the great sources of infestation. It has been found that the chalcis-fly frequently passes through one or two generations on this volunteer alfalfa before the seed fields are advanced to the point where infestation takes place. Every farmer, therefore, in an alfalfa seed-growing district should cut all of the standing alfalfa along the fences and waste areas at the time a hay crop is cut before he grows a seed crop. Alfalfa seed pods should not be allowed to develop anywhere around the field until the plants of the regular seed crop have begun to form pods.

CAREFUL CUTTING OF HAY CROPS.

It is of the greatest importance that special care should be exercised in cutting alfalfa or red clover before the seed crop is grown.

Any plants carelessly cut, so that some stems remain standing, and allowed to develop seed in advance of the regular seed crop, offer favorable conditions for the multiplication of the chalcis-flies. All pocket gophers should be poisoned or trapped and their mounds, as well as other irregularities in the surface of the field, should be leveled so as to make clean cutting possible.

PASTURING BEFORE GROWING SEED.

After removing the first crop of alfalfa for hay, and preparing to grow a seed crop, it is frequently possible to secure a herd of live stock, which may be turned into the field for two or three days. If a sufficient number of horses, cattle, or sheep can be secured they will render a valuable service by destroying the clusters of plants which frequently escape the mower, develop early seed pods, and form favorable breeding places for the development of the chalcis-fly before the regular seed crop has become sufficiently advanced.

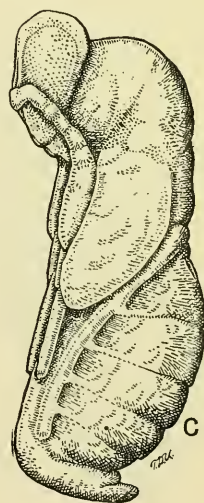
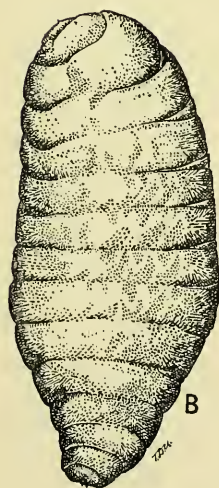
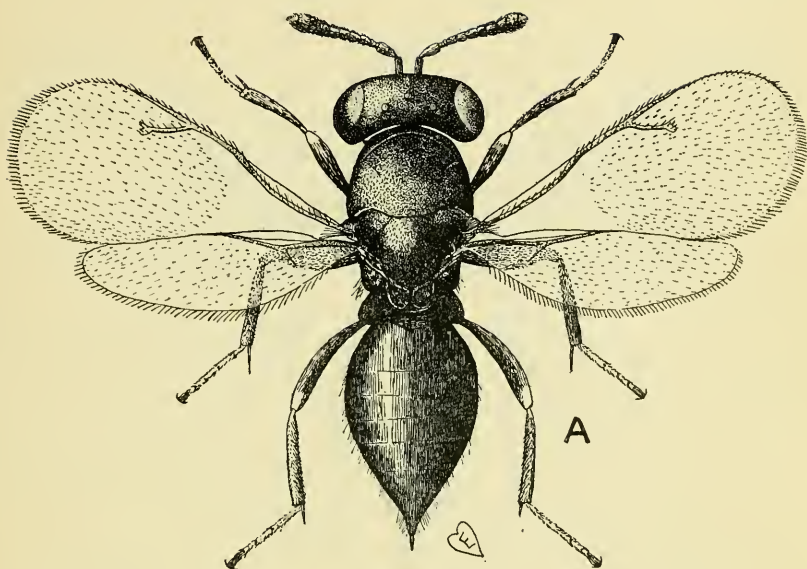
ALLOWING THE SEED CROP TO STAND TOO LONG.

The development of seed pods in the alfalfa seed fields is to a great extent periodical. That is to say, the first set of pods will have been formed when a new set of blossoms appears, or the first set of pods will be reaching maturity when the second set of pods is soft and green. This condition is most noticeable in fields receiving frequent irrigation. The tendency on the part of the farmer is to allow the seed crop to remain on the field too long, while waiting for a third or even a fourth set of pods to develop. It has frequently been observed that the chalcis-fly passes a complete generation in the earlier pods, and, in much greater numbers, infests the later pods forming on the same plants. Consequently, all seed fields should be handled, as much as possible, so that a heavy setting of pods will be secured with the first bloom and the crop removed from the field as early as possible. This will avoid a greater percentage of infested seeds as well as loss of time and will make room for the growing of subsequent crops for hay.

SECOND CROP OF SEED.

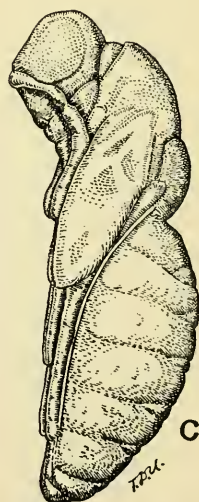
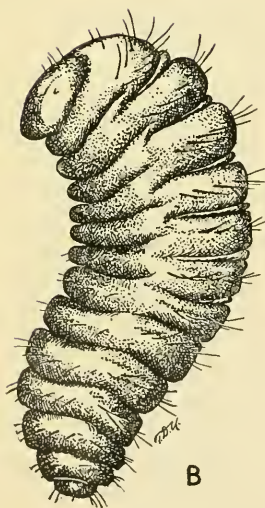
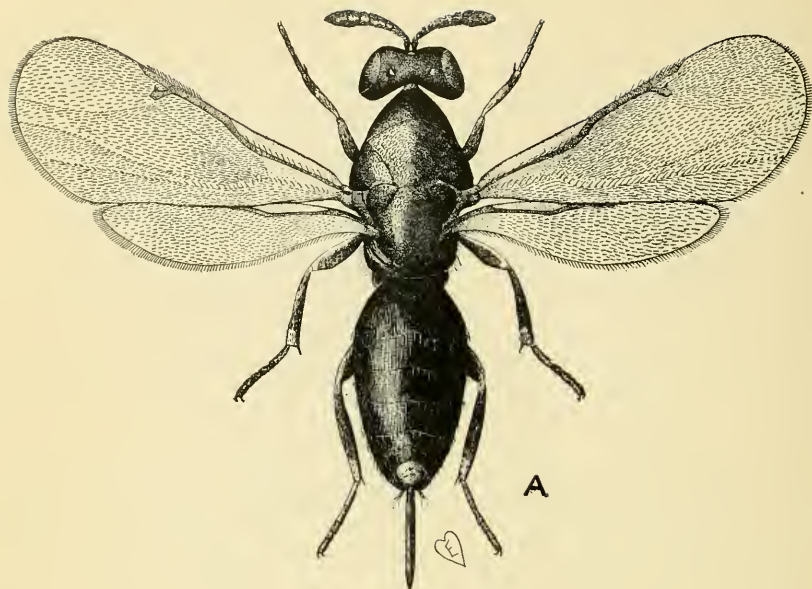
In the Southwest, where there is little danger of early frost, seed growers occasionally attempt to grow two crops of alfalfa seed in a single season. The results of such instances are usually very disappointing, on account of the usual severe infestation common to the second crop. This is frequently so great that the crop does not pay the harvesting expenses.

An attempt to grow a second crop of alfalfa seed in a single season will meet with almost certain failure as a result of the increased abundance of the chalcis-flies late in the summer.



EUTELUS BRUCHOPHAGI.

A ,Adult female; B ,larva; C, pupa.



LIODONTOMERUS PERPLEXUS.

A, Adult female; B, larva; C, pupa.

PASTURING INFESTED FIELDS.

The great mistake of pasturing alfalfa seed fields which have become too severely infested to yield a crop worth harvesting is too frequently made. Live stock walking through the ripe alfalfa cause the seeds to be shelled out and those infested with hibernating larvæ of the chalcis-fly fall on the ground, where they become the source of infestation for the following year.

HYMENOPTEROUS PARASITES.

TETRASTICHUS BRUCHOPHAGI Gahan (6).

*Tetrastichus bruchophagi*¹ (Pl. III) is generally distributed over most of the northern half of the United States. In the central California alfalfa seed-growing sections it is the most active of the present known parasites of *Bruchophagus funebris*. While it can not be depended upon to control the alfalfa-seed chalcis-fly, it has been observed to destroy about 50 per cent of the larvæ of the chalcis-fly normally in the fields. This species develops within the seed and feeds upon the larval stage of its host.

LIODONTOMERUS SECUNDUS Gahan (8).

*Liodontomerus secundus*² (Pl. IV) has been found by the writer to be an active parasite upon the chalcis-fly when the latter infests the seeds of red clover. It does not seem to attack the chalcis-fly larvæ infesting alfalfa seeds. This species is apparently most active in the red-clover seed-growing sections of Oregon and Idaho. It is active in the fields throughout the summer and hibernates in the larval stage within the infested seeds left on the field.

EUTELUS BRUCHOPHAGI Gahan (8).

*Eutelus bruchophagi*² (Pl. V) is of economic importance as a parasite of the chalcis-fly in the mountain valleys of southern Idaho and central Utah. It has also been found by the writer east of the Sierra Nevada Mountains in northern California. It does not appear to be present in the southwestern alfalfa seed-growing districts.

LIODONTOMERUS PERPLEXUS Gahan (8).

*Liodontomerus perplexus*² (Pl. VI) is a parasite of considerable importance in checking the abundance of the chalcis-fly breeding in alfalfa seeds throughout western Arizona. It was reared as far north

¹ For a more complete account of the species, see Urbahns (10).

² For a more complete account of this species, see Urbahns (11).

as South Dakota by C. N. Ainslie. This parasite attacks the larvæ of its host, and develops within the infested seeds. It has not been observed attacking the chalcis-fly when the latter infested seeds of red clover. This species is most active during midsummer. It appears slower in resuming activity in spring than the other species studied.

HABROCYTUS MEDICAGINIS Gahan (7).

*Habrocytus medicaginis*¹ (Pl. VII) is present throughout California, Idaho, Utah, and parts of Arizona. It has also been reported from South Dakota, Kansas, New Mexico, Nevada, and Oregon. While this parasite can not be depended upon at the present time to control the chalcis-fly in any locality where it has been observed, it is of value in checking the abundant development of its host. This species is parasitic externally upon the larvæ of its host, and completes its development within the infested seed.

From all observations, *Habrocytus medicaginis* attacks the chalcis-fly only when the latter infests the seeds of alfalfa. This parasite has never been found upon the same host within red clover seeds.

TETRASTICHUS VENUSTUS Gahan (7).

Tetrastichus venustus does not occur in sufficient numbers to be considered of economic importance as a parasite of the chalcis-fly in alfalfa seeds. While this species has been reared in small numbers from alfalfa seeds infested with the seed chalcis-fly, and is without doubt a parasite of the latter, the larval stage has not been recognized. Specimens were reared by the writer from Corcoran, Red Bluff, and Tulare, Calif., and from Yuma, Ariz.

TRIMEROMICRUS MACULATUS Gahan (6).²

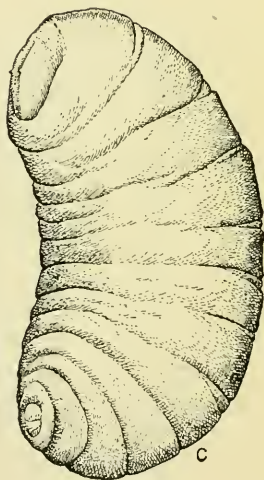
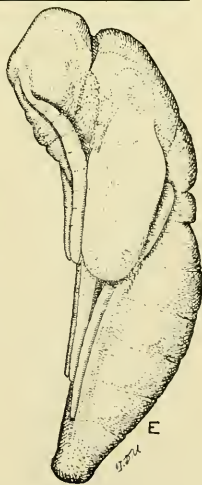
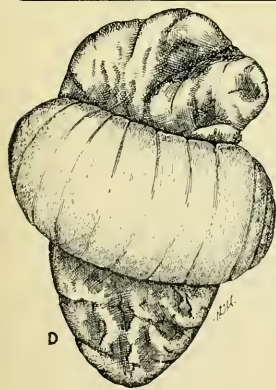
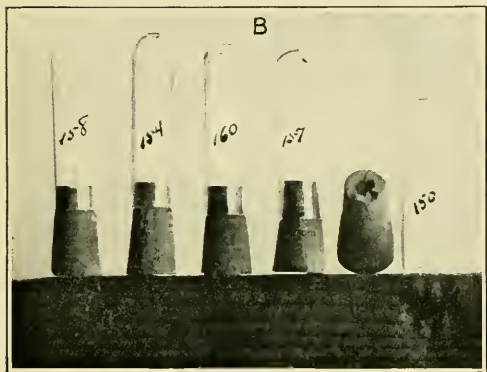
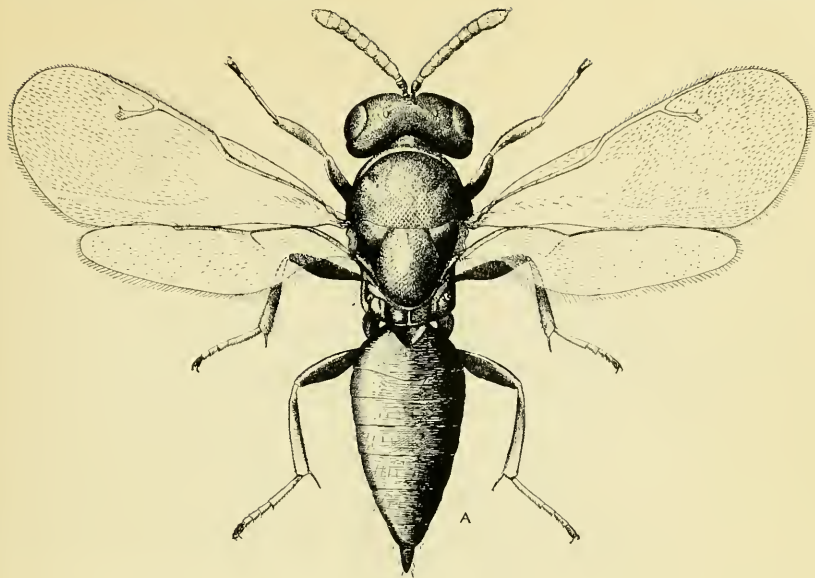
Trimeromicrus maculatus (Pl. VIII) is of economic value as a parasite of the alfalfa-seed chalcis-fly throughout Arizona and California. It has been found especially active in the Buckeye and Yuma Valley seed districts of Arizona, and in the Honey Lake and Imperial Valleys of California.

LIODONTOMERUS INSUETUS Gahan (8).

Notes on file in the Bureau of Entomology, made by H. T. Osborn, under date of September 19, 1910, show the larvæ of this species to be parasitic upon larvæ of *Bruchophagus funebris*. Specimens in the National Museum were reared by C. N. Ainslie, Mesilla

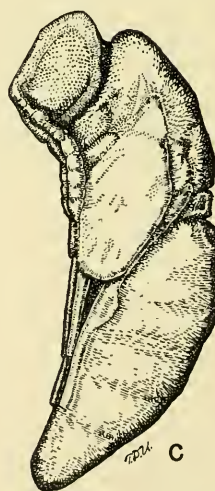
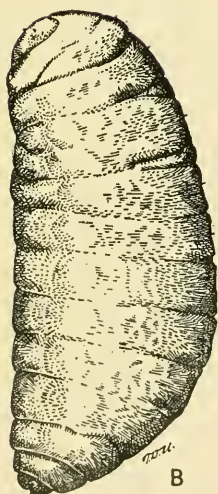
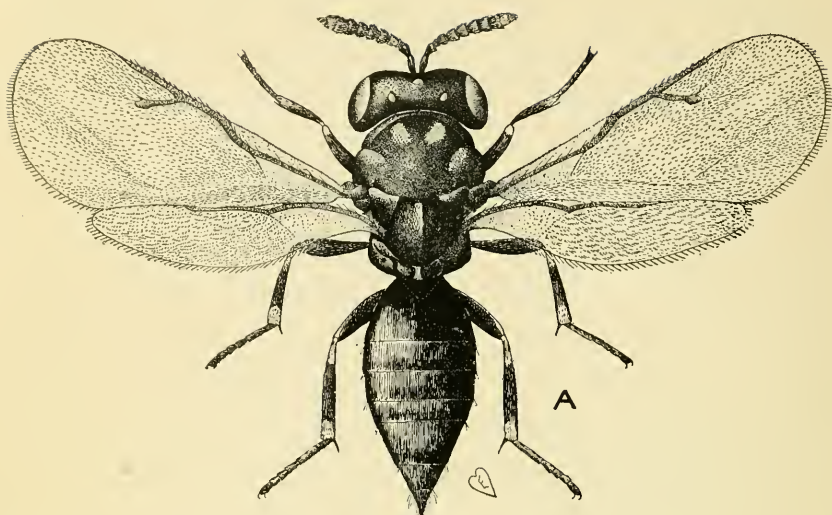
¹ For a more complete account of this species, see Urbahns (9).

² For a fuller description, see Urbahns (11).



HABROCYTUS MEDICAGINIS.

A, Adult; B, cages for rearing parasite larvae; C, larva; D, larva destroying its host larva; E, pupa.



TRIMEROMICRUS MACULATUS.

A, Adult female; B, larva; C, pupa.

Park, N. Mex.; H. T. Osborn and E. G. Kelly (1910), Wellington, Kans.; E. G. Smyth and R. N. Wilson, Tempe, Ariz.; and by E. G. Kelly, Sedgwick, Kans. (1914).

The economic importance of this species as a parasite of the chalcis-fly is not known at the present time.

EUELMUS sp.

A single larva of this species was dissected from an alfalfa seed by M. Marshall, and was found to be parasitic upon the larva of *B. funebris* infesting the seed. The specimen was taken at Pasadena, Calif.

The larva of this species measured about 1.6 mm. in length, and was almost white in color. The head was small and the chitinous mandibles distinctly visible. The body segments were conspicuous and covered with fine pubescence. The larva was rather active.

The pupa, at first white, turned to a smoky-white color, and almost black before the emergence of the adult.

PREDACIOUS MIDGE.

LESTODIPLOSIS sp. Felt.

Larvæ of a midge, described as *Lestodiplosis* sp. by Dr. E. P. Felt, were found in infested alfalfa seeds, where they had apparently destroyed the larva of *B. funebris*. It is quite probable that larvæ of this midge confine themselves to cracked or broken seeds, and where the larva of the chalcis-fly is exposed. The specimens under observation were taken in San Diego County, Calif.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 826

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.

PROFESSIONAL PAPER

August 10, 1920

GENERIC CLASSIFICATION OF THE
HEMIPTEROUS FAMILY APHIDIDAE

By

A. C. BAKER, Entomologist
Deciduous Fruit Insect Investigations

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Probably no group of insects has received more attention at the hands of economic entomologists than aphids, or plant-lice. Their interesting and often complicated biologies have attracted the attention of investigators, not only among entomologists, but among workers in the larger fields of zoology and general biology. While a large amount of work on the life histories and biologies of aphids has been done, corresponding progress in their classification has not been made. This is probably due to several causes, such as the lack of correlation of biologic and taxonomic facts, and the failure of aphidologists to consider sufficiently the results of the work of others.

On account of the great economic importance of aphids, and the necessity of their study in the development of control measures, the lack of knowledge concerning their systematic relationships results in much confusion. Some biologic workers, in fact, do not now attempt to give the name of the species being studied on account of the difficulty experienced in securing correct determinations.

¹This paper is the first of a series treating the Aphididae. It will be followed by others dealing with the economic importance, biologies, and relationships of species in the different genera.

The present work was undertaken in the hope of remedying such a condition to some extent at least. The genera of the world have been studied. Many workers have lent material and the large collections of the National Museum and Bureau of Entomology have been drawn upon. In the National Museum collection a large percentage of types has been available. To the study of preserved material have been added embryological, anatomical, and biological investigations that a better understanding of the natural relationships might be gained.

Besides many aphidologists in this country and abroad, who have given helpful suggestions and many of whom have read and criticized the manuscript, the writer is indebted to Dr. A. L. Quaintance, of the Bureau of Entomology, for the facilities for conducting many of the biological investigations which to a large extent have laid the foundation for the systematic treatment here given.

Superfamily APHIDOIDEA.

There appear to be two distinct families in the superfamily Aphidoidea. These are the Aphididae and the Phylloxeridae. The present paper deals only with the Aphididae.

Members of the Phylloxeridae differ markedly from forms belonging to the Aphididae. In the first place their biologies are quite different in that parthenogenetic oviparous forms occur during the summer. In the Aphididae only the sexed females which are produced in the fall are normally oviparous.

In structure the two families are separated at once by the formation of the stigma of the forewing. The wing itself seems very little different in an Adelges or Phylloxera from that in some of the specialized genera of the Aphididae. An examination of the freshly emerged wing, however, as has been pointed out by Dr. Patch, shows that the stigma in the Phylloxeridae is formed by the radial sector and the stigmal vein is the media. In the Aphididae, on the other hand, the stigma is formed by radius₁ and the stigmal vein is the radial sector. The two families may thus be separated as follows:

KEY TO THE FAMILIES OF THE APHIDOIDEA.

Summer parthenogenetic oviparous forms produced: Stigma formed by the radial sector PHYLLOXERIDAE.
Only sexual oviparous forms produced: Stigma formed by radius₁ APHIDIDAE.

A word of explanation in regard to the name Phylloxeridae may be necessary. The genus *Chermes* was erected by Linnaeus in 1758 and in 1862 was replaced by *Psylla* Geoffroy. For this genus *Chermes ficus* L. was set as type by Lamarek in 1801. *Ficus*, therefore, becomes *ipso facto* the type of *Chermes*, and Chermidae the family name of the "jumping plant-lice." The family name for the aphidoidean group, therefore, is derived from the genus *Phylloxera* Boyer (1834).

PHYLOGENY OF THE APHIDIDAE.

In many published classifications of the Aphididae those groups which according to the writer's conception are the most specialized have been placed as the most primitive. This is the case with those

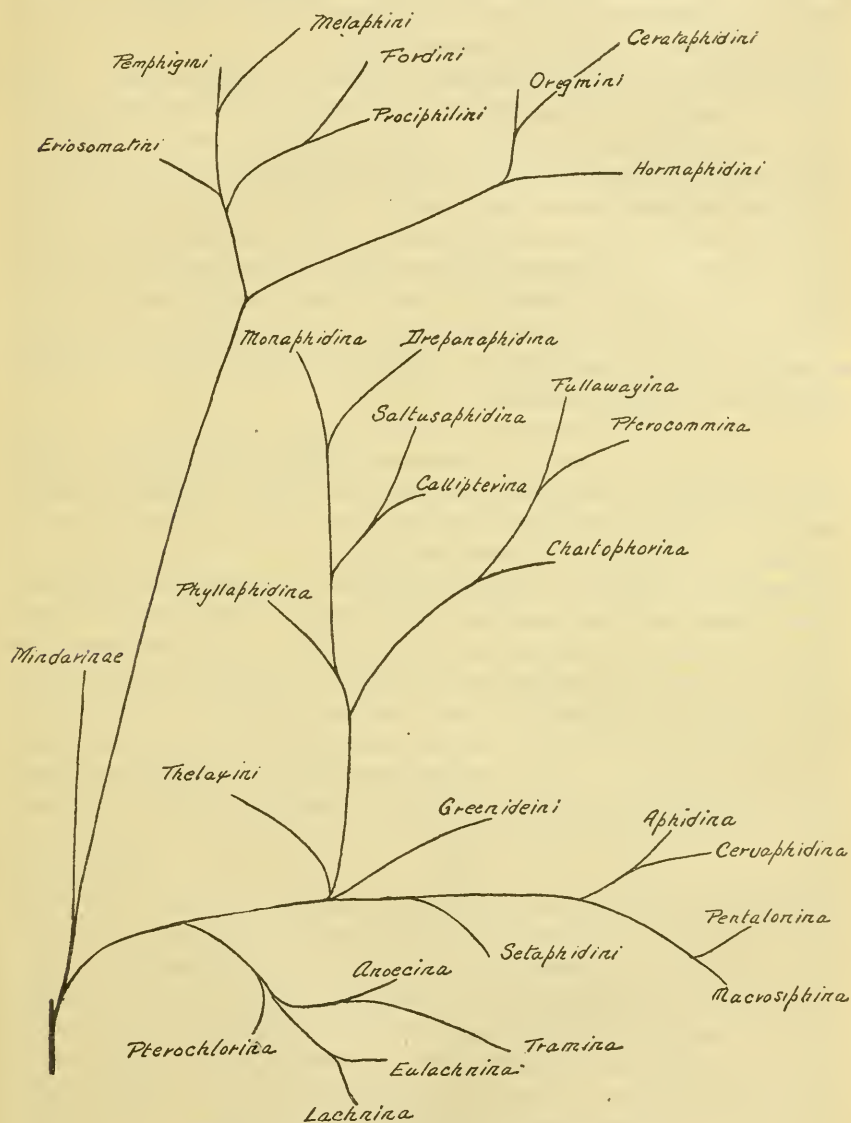


FIG. 1.—Phylogeny of the hemipterous family Aphididae.

insects forming in the present classification the Eriosomatinae and the Hormaphidinae.

A study of the anatomy and the biology of aphids makes it evident that there are three main groups of living forms for which subfamily

names are here used: Aphidinae, Eriosomatinae, and Hormaphidinae. Besides these there is the one species, in some ways a relic of the past, forming the Mindarinae.

As will be seen by the diagram (fig. 1), the Aphidinae is considered the most primitive subfamily of the three main groups. This is substantiated by the habits of the insects, by the structure of the wings, beak, etc., and by the sexual forms.

Practically all of these insects are foliage or twig feeders. They live, as a rule, in colonies and have not developed any very special methods of life, such as highly complex gall formation. With the exception of the Mindarinae the most primitive wing structure occurring in the family is met with here. The media is most commonly twice branched throughout the subfamily and even in the Mindarinae there is more of a reduction than this. The antennæ are of six segments, the largest number found in the family, and the sensoria are simpler in nature than those met with in the other two large subfamilies. The beak in the Lachnini shows also a primitive condition in its segmentation.

The sexual forms are most primitive in the Aphidinae. Winged sexes often occur, at least the males are very commonly winged. Both sexes still retain their beaks and feed on their hosts in the same way as do the other forms, and the ovaries of the female develop normally, and she produces several eggs.

When the phylogeny of this subfamily is studied, there becomes evident the primitive character retained by the Lachnini. In these forms the beak structure and the nature of the antennæ and cornicles point to a primitive condition. The sexes, too, indicate this, though not markedly more than in other tribes. But the fact that these forms are mostly conifer feeders should not be overlooked. It is the opinion of the writer that this is a primitive habit. The Lachnus branch, therefore, may be considered the lowest branch of the Aphidinae. If the wings of fossil aphids be examined it will be seen that by far the greater number of them possess a wing structure quite different from that of our living forms. The radial sector arises back of the stigma, which is usually very long and narrow. This character is retained probably only in the Mindarinae. It is evident, then, that during the development of the present Aphidinae this vein migrated toward the tip of the wing until it came to stand either in the middle of the stigma or near its tip. On one line of this migration is the Lachnina wherein the vein has reached nearly to the tip of the wing and become short and straight. The remaining characters apart from the wings have in these forms remained quite primitive. The subtribe Eulachnina is evidently a more specialized group on this same line of development, for it possesses

the same type of wing. Therefore this subtribe is considered quite closely related to the subtribe Lachnina but differing from it in specialization of body form, cornicles, and eyes. The other subtribes of the Lachnini have quite a different wing structure. While the radial sector has changed its position considerably from that found in the fossils it has not reached the tip of the stigma and is not straight, but much curved. In this regard, therefore, the *Pterochlorina* is perhaps the most primitive subtribe in the Lachnini, although in many respects it is specialized. On the other hand there are two highly specialized subtribes, the *Anoecina* and the *Tramina*. It is usually the custom to place the *Anoecina* with the *Pemphigina*. Its relations, however, are here. The adult forms are very similar indeed to the lachnids. The sexual forms, on the other hand, are small and apterous and suggestive of the sexes of the *Eriosomatinae*, and there is considerable ground for placing the *Anoecina* there. These sexual forms, however, seem to differ quite distinctly from those of the *Eriosomatinae*, which are beakless and the oviparous female of which never develops more than one egg. The development of the stigma shows quite an extreme modification from the long, narrow, primitive stigma.

Near this same line of development is the rather highly specialized subtribe *Tramina*. The most marked character of this subtribe is the extreme modification of the hind tarsi. In considering only the genus *Trama* it might be thought that the tribe should belong with the *Eriosomatinae*. The species *troglydites* has often been figured with cornicles in the apterous form. Specimens from Mordwilko and Schouteden determined as this species lack them and the writer therefore considers *Trama* as the most specialized genus in the subtribe. Another genus represented by *radicis* Kalt. shows cornicles very large and of a typical *Lachnus* character. Through this genus, therefore, the subtribe can be placed at once with its relatives in the Lachnini. Apart from the peculiar tibial character this genus is very lachnid-like.

The next branch from the Aphidinae is the *Callipterus* branch, which may be considered as arising somewhat later than the *Lachnus* branch. From this offshoot soon after it arose and before the present genera of the *Callipterini* appeared the *Thelaxini* separated.

This tribe, the old *Vacuini*, also has usually been placed with the *Eriosomatinae*. There are some resemblances, it is true; only one egg, for instance, is usually laid by the sexual female. But this is not always the case, for, according to Buckton, more than one egg is sometimes laid. Such a condition shows that the one egg habit is of much more recent development than in the *Eriosomatinae*. Moreover, the sexual female is very different in structure. She is not the

degenerate, beakless, nonfeeding individual of the Eriosomatinae, but feeds upon the leaf like the viviparous forms. Moreover, in external structure these insects resemble certain ones of the Callipterini, to such an extent, indeed, that Davidson has described one of these forms as a Chaitophorus. Certain of the structures met with in these forms resemble those found in the Hormaphidinae and on these structures the tribe might be placed there. The writer believes, however, that the true affinities of the tribe are shown by comparison with the Phyllaphidina. It will be seen at a glance that there is a very close resemblance in all main characters. But the sexual forms are different, although not so strikingly different as would appear at first. In the Phyllaphidina both winged and wingless ovipara and as a rule winged males occur. But in some species (*quercifoliae*) intermediate and apterous males also occur. It is not a very long call, therefore, from the apterous males and females of the Phyllaphidina to the apterous sexes of the Thelaxini. But the habit of egg laying met with in this last tribe shows that it has been on this course of development longer than has the Phyllaphidina. The group is therefore considered as a tribe which has separated somewhat earlier and yet has paralleled in some ways certain characters of the Phyllaphidina.

Continuing with the Callipterus branch we find two somewhat similar lines of development, the one represented by the Callipterina and the other represented by the Chaitophorina. Both are similar in many regards, but are quite different in the armature, particularly of the antennæ.

The first subtribe separating from that offshoot represented by the Callipterina is the Phyllaphidina. This seems evident from the fact that the oviparous forms of some species are yet alate, a primitive condition found very seldom in the Aphididae. The next offshoot resulted in the Callipterina where the oviparous forms are apterous, the cornicles of moderate development, and the wing veins usually not reduced. From this offshoot the Saltusaphidina evidently arose. This little subtribe is closely related to the Callipterina in many ways, but there are some new developments. In the first place the power of leaping has become developed by the enlarging of the femora. Secondly, both the sexual forms have lost their wings, which the male usually retains in the Callipterina. One of the most important points, however, is the fact that in the Saltusaphidina the ocular tubercles which represent the retained larval eyes are absent, whereas they are quite conspicuous in the Callipterina.

On this same Callipterus branch, but somewhat more specialized than the Callipterina, are two subtribes. These have specialized in opposite directions, the one toward the elimination of the cornicles

and the other toward the development of them. The first subtribe, the Monaphidina, lacks cornicles above. The second of these two, the Drepanaphidina, possesses them in varying degrees. In this last subtribe the males are winged, and the females have developed an extremely long, narrow ovipositor.

Coming now to that line represented by Chaitophorus, the Chaitophorina are found to be the most generalized, corresponding quite closely with the Callipterina. In this subtribe males are winged as a rule, but sometimes in the same species they are intermediate or apterous. Arising from the same branch with the Chaitophorina are two subtribes specialized in different directions, like the subtribes of Callipterus. The first, Fullawayina, lacks cornicles entirely, whereas the Pterocommina has developed them in varying degrees, as has the Drepanaphidina. This concludes the subtribes of the Callipterus branch.

In connection with these insects the tribe Greenideini should be considered. The cornicles of the primitive aphids were evidently small, somewhat rounded or conical, and armed with hairs. In the Greenideini the insects have very long cylindric or somewhat swollen cornicles which are thickly covered with prominent hairs. No such well-developed cornicles are met with in any of the other tribes of the family, although they are approached in the Macrosiphina. In this latter subtribe species occasionally occur which show a few short hairs on the cornicles. It seems evident then that the Greenideini separated from the Aphidinae before the hairs of the cornicles disappeared. This was evidently more recent than the development of the tribe Lachnini which possesses a much more primitive cornicle. At about the same time that the ancestors of the Callipterini separated from the Aphidinae, other forms probably separated and more or less paralleled in some ways the ancestors of the Macrosiphina, but unlike them carried the hairs of the cornicles. They thus resulted in forms with very long cornicles similar to those of the Macrosiphina but armed with long hairs. In other characters, too, they of course differ, particularly in regard to the cauda.

In considering the further development of the Aphidinae, a more or less distinct development of the cornicles and antennal tubercles is found. There are thus two types which separate themselves, represented by Aphis and Macrosiphum respectively. These may be considered as leaving the aphid line at about the same time after the development of prominent cornicles. There are, consequently, two subtribes, the Aphidina and the Macrosiphina. The Cervaphidina represents a group of insects armed with long, somewhat cylindric cornicles, and very prominent spinelike protuberances. The number of antennal segments is somewhat reduced, as is also the wing venation. It seems evident then that this is a subtribe on somewhat the

same line of development as the Aphidina but developing these specialized spines during the same period in which the wings and antennæ have become reduced. Still another subtribe, the Pentalonina, shows a very peculiar wing venation. This is not so much a primitive wing as a more specialized one. It is placed, therefore, as one of the highest subtribes of the Aphidini.

There remains yet for discussion the tribe Setaphidini. This, it seems evident, belongs with the Aphidinae. In regard to the antennæ and the wings it is quite highly specialized but in regard to the cornicles, cauda, and anal plate this statement can not be made. The natural position of this tribe is somewhat doubtful. Its ancestors evidently separated from the aphidian line before the prominent cornicles of the Aphidina, Macrosiphina, etc., appeared and yet the species are more specialized in many ways than are members of those subtribes. It would appear that the lines separated after that of the Greenideini, for the cornicles are not hairy. Yet this separation must have taken place a considerable time before that of the Aphidina and Macrosiphina. The tribe is placed, therefore, as indicated in the diagram (fig. 1).

The subfamilies, other than the Aphidinae, include the most specialized members of the family. By far the most primitive of these subfamilies is the Mindarinae. This subfamily, as has been indicated, is a remnant from the past, giving some idea of the ancestors of the Eriosomatinae and the Hormaphidinae. The wing structure is particularly worthy of study. The wing of no other living aphid is like it, but this peculiar structure is abundantly met with in fossil forms. The media, it is true, is more reduced than in certain members of the Aphidinae, but this is of very little importance as compared with the wing's peculiar structure. The form also feeds upon conifers and this is undoubtedly a primitive habit. The cauda and anal plate are unlike those met with either in the Eriosomatinae or the Hormaphidinae.

The sexual forms are interesting. They have become sufficiently specialized toward the Eriosomatinae to have lost the wings, but they retain the beak, at least in most individuals, and feed. The ovaries of the oviparous female also are developed so that a number of eggs are laid.

The two remaining subfamilies are the most highly specialized of all aphids.

The Eriosomatinae are in many ways more specialized than the Hormaphidinae, but in other ways they are more primitive. The whole Eriosoma line separates at once on the sexual forms. These are small, apterous, and beakless. Throughout their life they take no nourishment, and the ovaries of the oviparous female become atrophied, so that only one develops and of the eggs therein only one

reaches maturity. The most primitive tribe on this line is the Eriosomatini. The forms of this tribe are not as a rule distinct gall formers. They possess rather prominent cornicles and have developed special wax glands. They live as a rule upon deciduous trees, the summer forms of many species alternating upon the roots of plants.

More specialized than the Eriosomatini are the Pemphigini, which, however, are very similar to the former in many respects. These are distinct and true gall formers on deciduous trees. For part of the year they are usually altogether closed within the gall. Wax secretion is common and the cornicles are present, but reduced to mere rings.

The Melaphini are closely related to the Pemphigini and are gall formers like them. These forms, however, have lost entirely the cornicles which are usually still retained in the Pemphigini.

A somewhat different specialization is met with in the Prociphilini. Here wax secretion has developed at the expense of the cornicles so that these organs are absent, at least in nearly all the forms of the species. Large wax plates have taken their places. The species are not true gall formers, but live upon foliage which they cause to roll or crumple into a pseudogall. Development along this line is also present in the next tribe, the Fordini.

Here the cornicles are also absent, being replaced by large wax glands, but the species are nearly all root feeders and are usually associated with ants, often living with them in their nests. This tribe may be considered the most specialized of all the Eriosomatinae.

The same specialization in the sexual forms has not occurred in the Hormaphidinae. They are small and apterous, it is true, but they possess beaks, they feed, and the oviparous female lays more than one egg. In one regard, however, these insects are more specialized. Many of them have developed a peculiar aleyrodiform stage, which is quite different from anything occurring elsewhere in the family. Along with this development peculiar wax glands have made their appearance so that some of these forms look very much like aleyrodids and are indeed often mistaken for them.

The most primitive tribe here is the Oregmini, which, although it possesses many of the other characters met with in these forms, lacks the aleyrodiform stage. These insects possess quite distinct cornicles.

Closely related to the Oregmini is the Cerataphidini. These insects likewise possess cornicles and in several ways suggest the Oregmini, but they have developed a distinct aleyrodiform stage and in this regard are much more advanced than the members of that tribe.

Lastly, and perhaps most specialized of all, are the Hormaphidini. These insects are curious gall formers, not only on their primary host, but often on their secondary one as well. They lack cornicles and

have developed aleyrodiform generations and wax secreting structures. In many ways the specialization of these insects is most remarkable.

KEY TO THE SUBFAMILIES OF THE APHIDIDAE.

1. Sexual forms small with functioning mouth parts absent. Oviparous female with all the egg tubes present or indicated in the embryo but the adult possessing only one tube and maturing one cell so that one egg only is laid. Cornicles much reduced or absent. Wax glands abundantly developed. Wing veins usually reduced. Antennal sensoria prominent.....ERIOSOMATINAE.
- Sexual forms with functioning mouth parts. Nearly all the ovarian tubes developed in the adult oviparous female..... 2.
2. Radial sector of forewing inserted mesad of the stigma. Sexes small. Oviparous female laying several eggs.....MINDARINAE.
- Radial sector not so inserted but arising from the stigma..... 3.
3. Forms usually gall makers. Wing veins much reduced so that the media is usually simple. Wax glands usual. Antennal sensoria annular. Aleyrodiform stages common. Sexes wingless as a rule and small..HORMAPHIDINAE.
- Forms not usually gall makers. Wing veins often not reduced. Wax glands not abundant. Antennal sensoria oval or subcircular. Aleyrodiform stages rare. Cornicles often little reduced. Winged males common.

APHIDINAE.

Subfamily I, APHIDINAE.

The subfamily Aphidinae contains many of the most primitive insects in the family. Indeed, with the exception of the Mindarinae the subfamily may be considered as by far the most primitive.

The oviparous female, in all the tribes, develops the ovaries in a normal way and lays several eggs. An exception to this, however, is the Thelaxini, but here two or more eggs are sometimes laid. The males may be either alate, apterous, or intermediate, and in many species which possess the migratory instinct they are often produced on quite a different food plant from the oviparous form. The stem mothers are in practically all cases apterous, but the remaining generations throughout the year may or may not be winged. In many species a larger percentage of winged forms occurs in certain generations and a larger percentage of apterous forms in others. In some species, however, this does not appear to be the case. In certain of the Callipterini practically all of the viviparous forms other than stem mothers are winged.

The insects are mainly foliage feeders, but they also attack the stems and roots. They occur both upon woody plants and herbs. Their feeding may have little apparent effect upon the host or it may cause distortions or pseudogalls. Some species are particularly injurious to their hosts and when these are economic plants cause much loss.

Great variation is met with amongst the members of the subfamily. The antennæ are rather long and slender and as a rule are armed with subcircular sensoria. In most of the forms the sixth segment

possesses an elongate narrow-unguis, which in some of the Callipterini and Aphidini is remarkably developed. In the more primitive groups, however, this is short and thumb-like. The head of the apterous form differs much from that seen in the Eriosomatinae, in that true compound eyes are present and often very prominent, and the small larval eyes are seen as ocular tubercles. It is noteworthy that in the Eriosomatinae the alate forms possess distinct compound eyes but the apterous forms have lost them. The wings are in general quite similar throughout the family in regard to the venation. In color, shape, and location of the veins there is often considerable difference. Moreover, there are a few genera amongst the different tribes which show abnormal wing form, of which genera *Microparsus* is a good example. In the typical forms of this subfamily the media of the fore wing is twice branched, but it is very commonly branched only once and it is rarely simple.

The cornicles show remarkable variation. In some forms of the Callipterini they are short and slightly swollen at the base, in the Lachnini they are low broad cones, whereas in the Greenideini they are cylindrical and sometimes longer than the body. Between these extremes every gradation occurs. The cornicles may be straight or they may be swollen to a greater or less degree. Practically all forms eject a colored wax from these organs when disturbed.

The cauda shows almost as much variation as the cornicles, sometimes being short and rounded, in other cases elongate, spatulate, or conical, and in others distinctly knobbed. Variation also is met with in the anal plate, though this usually is rounded. In the Callipterini, however, it is often bilobed.

The tribes of the subfamily may be separated as follows:

KEY TO THE TRIBES OF THE APHIDINAE.

1. Cornicles situated on broad flat cones..... 2.
 Cornicles truncate, or more or less elongate..... 3.
2. Cornicles and antennæ hairy. Antennæ with the unguis short and thick..
- LACHNINI.
- Cornicles and antennæ not hairy. Antennæ with the unguis long and slender SETAPHIDINI.
3. Cornicles clothed with long hairs..... GREENIDEINI.
 Cornicles never with long hairs..... 4.
4. Thorax of alate form with the lobes not prominently developed; oviparous form small, often laying one egg. Large wax plates present..... THELAXINI.
 Thorax of alate form with the lobes prominently developed; oviparous female laying several eggs. Large wax plates usually absent..... 5.
5. Cornicles truncate or elongate; when elongate the cauda knobbed, and the anal plate bilobed, or the antennæ prominently hairy..... CALLIPTERINI.
 Cornicles not truncate, usually elongate. Cauda never knobbed. Antennæ with only a few spinelike hairs..... APHIDINI.

Tribe LACHNINI.

The tribe Lachnini is the most primitive of all living aphids, with the exception of the Mindarinae. The genus *Mindarus* shows in its wing structure characters more primitive than any of the Lachnini, but in other characters such as those of the beak, cornicles, cauda, sensory structures, etc., the Lachnini are very primitive insects. In examining the fossil wings it is to be noted that the radial sector is situated back of the stigma. In practically all living aphids, with the exception of *Mindarus*, this vein has migrated toward the tip of the wing. In primitive forms the stigma is long and narrow, whereas in most living forms it has become more or less compact. In the subtribe Lachnina the radial sector has become a very short, straight vein almost at the tip of the wing. This shows that the Lachnina are evidently more advanced than the Pterochlorina in which the radial sector is somewhat curved and situated near the middle of the stigma. The subtribe Eulachnina is considerably specialized, as indicated by the eyes, the shape of the body, and the cornicles. It is, however, as closely related to the Lachnina as are any of the other tribes, as will be seen from the formation of the wing. The Anoecina in the typical genus shows a wing with a short blocky stigma, a condition quite different from that seen in the Lachnina, and the radial sector is here curved. (In *Nippolachnus*, however, the stigma is still long and straight.) Moreover, the sexual forms are more specialized, being apterous in both cases. Anoecia, therefore, is somewhat removed from Lachnus. The genus *Trama* is considerably specialized, in that it lacks cornicles in the apterous form. It is, however, related to Lachnus through *Neotrama* with small cornicles, and *Protrama* with large hairy cornicles.

The rostrum in the Lachnini is in many species five-segmented, a primitive character most marked in this group. The freshly emerged wing of a lachnid shows that M_1 , M_2 , and M_{3+4} are the veins represented when the media is twice branched, and that in some species no vein is formed about M_2 . The cubitus and first and second anal are present in the forewing. As in other Aphididae, however, no vein forms about the second anal. The radial sector is in Lachnus a short, straight trachea and a prominent vein forms about it. The stigma, as in all members of the family, is formed by $radius_1$. In the hindwing both media and cubitus are present and form distinct veins.

The antennae of the Lachnini are six-segmented with a short unguis. They are usually armed with oval or subcircular sensoria and prominent hairs. In fact, the entire body of the insect is hairy.

The cornicles are characteristic. They are situated on distinct cones which are constricted before the somewhat flanged opening which is not situated over the center of the cone. The cones are arm-

ed with hairs. Some specialized forms have small cornicles or none at all. Wax-secreting structures, but no distinct gland areas, are present in this tribe and a coating of fine wax is often found over the entire insect, including the appendages. This is true of the oviparous forms, as well as of the viviparous ones.

The cauda and anal plate are here rounded, never developed into elongate structures as in some of the other tribes of the subfamily. The sexual forms are nearly as unspecialized as the viviparous ones. Both sexes possess a distinct rostrum and take food. The males in the typical subtribes are winged. The females are apterous, but the ovaries are developed and several eggs are laid by each individual.

KEY TO THE SUBTRIBES OF THE LACHNINI.

- | | |
|--|----------------|
| 1. Radial sector of fore wings curved and of moderate length..... | 2. |
| Radial sector of fore wings short and straight, situated near the tip of the wing..... | 4. |
| 2. Hind tarsi extremely elongate, head divided, wing venation usually faint. | |
| Hind tarsi normal..... | 3. |
| 3. Stigma short and thick, sexes both apterous..... | ANOECINA. |
| Stigma elongate, males often winged..... | PTEROCHLORINA. |
| 4. Form elongate and very narrow; antennæ with bristles, cornicles not hairy; eyes without ocular tubercles..... | EULACHNINA. |
| Form not elongate; cornicles on hairy cones; eyes with ocular tubercles.. | LACHNINA. |

Subtribe ANOECINA.

The subtribe Anoecina is suggestive of the Tramina, but none of the forms are as specialized as some of the genera of that subtribe. The typical genus is quite distinctive in the short rounded stigma and in the sexual forms. The genus *Nippolachnus*, however, has a stigma quite *Lachnus*-like in appearance. Only two genera are known at present.

KEY TO THE GENERA OF THE ANOECINA.

- | | |
|--|---------------|
| 1. Head not divided; eyes with prominent ocular tubercles; stigma of wing short and rounded..... | Anoecia. |
| 2. Head divided; eyes without ocular tubercles; stigma long and straight. | Nippolachnus. |

Genus ANOECIA Koch.

Plate I, A-F, I.

1857. *Anoecia* Koch, Die Pflanzenläuse Aphiden, p. 275.

Characters.—Head not divided, front somewhat rounded. Eyes prominent but not distinctly set off from the head. Antennæ of six segments, armed with subcircular or oval or elongate sensoria and covered with hairs. Fore wings with the media once branched. Stigma short and thick. Hind wings with both media and cubitus present. Cornicles situated on broad hairy cones. Cauda and anal plate somewhat rounded.

Spring forms free, living in colonies; summer forms often subterranean. Sexes small and apterous, possessing beaks and feeding. Oviparous female laying one or more than one egg.

Type (monotypical), *Aphis corni* Fab.

Genus *NIPPOLACHNUS* Matsumura.

Plate I, G, H, J, K.

1917. *Nippolachnus* Matsumura, Journ. Coll. Agr. Tohoku Univ., v. 7, pt. 6, p. 382.

This genus is closely related to *Anoecia* Koch and yet it retains many *Lachnus* characters which are not present in *Anoecia*. It is separated from that genus by several important points. The head is distinctly divided as it is not in *Anoecia*. The stigma is long and *Lachnus*-like and the eyes have not the small prominent ocular tubercles of *Anoecia*, but are rounded on their posterior margins.

Characters.—Antennæ of six segments, armed with prominent protruding sensoria and many hairs; head divided; eyes without prominent ocular tubercles. Wings with the media once branched, the stigma rather long and narrow. Cornicles on large broad cones entirely covered with hairs.

Spring forms free, migrating in summer to alternate hosts. Sexes small, males winged.

Type (fixed by Matsumura, 1917), *Nippolachnus piri* Mats.

Subtribe *EULACHNINA*.

The subtribe *Eulachnina* is related to the *Lachnina* quite closely, as can be seen by the wing structure where the radial sector is a straight, short vein extending across the tip of the wing. The media also is faintly indicated. In the other branch of the tribe in which the *Anoecina* and *Tramina* are found, the radial sector is curved as it is in *Aphidina*, etc. Members of the *Eulachnina* may, however, be separated at once from the *Lachnina* on the elongate, narrow shape of the body, the abruptly rounded cauda, the character of the cornicles, and the absence of ocular tubercles upon the eyes. The subtribe is evidently quite specialized as compared to the *Lachnina*.

Characters.—Eyes large and set off from the head; ocular tubercles not evident; antennæ slender, armed with bristles or spines, not slender hairs. Cornicles shallow, not on distinct hairy cones. Cauda abruptly rounded. Body very elongate and slender, scarcely wider than the head.

KEY TO THE GENERA OF THE *EULACHNINA*.

- | | |
|--|----------------------|
| 1. Antennæ of five segments, armed with minute bristles..... | <i>Essigella</i> . |
| Antennæ of six segments..... | 2. |
| 2. Media once branched, antennæ with long stout spines..... | <i>Eulachnus</i> . |
| Media twice branched..... | <i>Todolachnus</i> . |

Genus *ESSIGELLA* Del Guercio.

Plate I, S-Y.

1909. *Essigella* Del Guercio, Rivista Patol. Vegetale, n. s., v. 3, p. 329.

The genus *Essigella* is quite similar to *Eulachnus* with the exception of the antennæ.

Characters.—Head with large outstanding eyes, very much broader than long. Antennæ of five segments, imbricated, armed only with a few minute bristles. Fore wings with the media faintly indicated, once branched, hind wings with both media and cubitus present. Cornicles chitinated rings situated close to the body, no hairy cones present. Cauda rounded. Body elongate and narrow.

Type (monotypical), *Lachnus californicus* Essig.

Genus *EULACHNUS* Del Guercio.

Plate I, L-R.

1853. *Cinaria* Curtis, British Entomology, v. 12, section 576.

1909. *Eulachnus* Del Guercio, Rivista Patol. Vegetale, n. s., v. 3, p. 329.

1915. *Protolachnus* Theobald, Bull. Ent. Res., v. 6, p. 145.

Del Guercio erected the genus *Eulachnus* without setting a type, but Wilson¹ has indicated *agilis* Kalt. as the type. Apparently, therefore, the genus must be based upon that species. Theobald's genus was based on his *tuberculostemmata*, a species in which the characters are the same. *Cinaria* was erected with *pini* L. as type, but this was questioned.

Characters.—Head divided, eyes rather large and outstanding; antennæ of six segments, armed with long stout bristles. Fore wings with the media faintly indicated and once branched; hind wings with both media and cubitus present but faint; cornicles minute rings, not situated on hairy cones. Cauda abruptly rounded. Body elongate and narrow.

Type (fixed by Wilson, 1911), *Lachnus agilis* Kalt.

Genus *TODOLACHNUS* Matsumura.

1917. *Todolachnus* Matsumura, Jour. Coll. Agr. Tohoku Univ., v. 7, pt. 6, p. 381.

The writer has been unable to study the type of this genus, but from the description given it seems to represent a genus belonging here and having a twice-branched media. The description of the cornicles as "wart-like, not broader at base" would indicate its affinities here, also the words "body long, nearly parallel on the lateral sides."

Type (fixed by Matsumura, 1917), *Todolachnus abietis* Mats.

Subtribe *LACHNINA*.

The members of the subtribe *Lachnina* may be separated from those of other subtribes with the exception of the *Eulachnina* by the character of the venation. The radial sector here has almost reached the tip of the wing and become a short straight vein. The genera may be separated as follows:

KEY TO THE GENERA OF THE *LACHNINA*.

1. Media of fore wings twice branched..... *Dilachnus*.
Media not twice branched..... 2.
2. Media once branched..... 3.
Media simple..... *Unilachnus*.
3. Labium lance-like..... *Lachnus*.
Labium obtuse..... *Schizolachnus*.

Genus *LACHNUS* Burmeister.

1835. *Lachnus* Burmeister, Handbuch der Ent., v. 2, pt. 1, p. 91.

1909. *Lachniella* Del Guercio, Redia, v. 5, p. 286.

The genus *Lachnus* Burmeister was erected with the following included species: *lapidarius* Fab., *fagi* Linn., *quercus* Linn., *fasciatus* Burm., and *punctatus* Burm.

Of these species the following were removed as types of other genera: *fagi*, 1857, *Phyllaphis*, and *quercus*, 1870, *Stomaphis*.

¹ Wilson, H. F. Notes on the synonymy of the genera included in the tribe *Lachnini*. In Ann. Ent. Soc. Amer. v. 4, p. 51-54, 1911.

The following type fixations have been made for *Lachnus*:

- 1840. *Aphis roboris* Linnaeus, Westwood.
- 1863. *Lachnus pinicola* Kaltenbach, Passerinl.
- 1908. *Aphis nudus* De Geer, Mordwilko.
- 1910. *Lachnus punctatus* Burmeister, Wilson.
- 1911. *Lachnus fasciatus* Burmeister, Wilson.

Now the first three fixations are invalid, since the species were not included in the original genus. The first valid fixation, therefore, is that of Wilson, 1910, when he set *punctatus* as type. This fixation, according to present rules, can not be changed in 1911 because it is an unfortunate fixation, but *punctatus* must remain the type of the genus *Lachnus*. The question is now purely zoological. At present *punctatus* is unknown and, therefore, the genus *Lachnus* must remain unknown until *punctatus* is discovered. This is the situation, if the rules are followed, and the well-known genus name will be lost to us. At the suggestion of numerous aphid workers we are holding *fasciatus* as the type of *Lachnus* and the Commission will be asked to suspend the rules in this case on account of the long usage of the name *Lachnus*.

In 1909 Del Guercio erected the genus *Lachniella* without setting a type but in 1911 Wilson interpreted this genus as *Lachnus* with *fasciatus* Burm. as type. Following this the writer definitely designated this species as type. Therefore, *Lachniella* will become a synonym of *Lachnus*.

Characters.—Eyes large, with distinct ocular tubercles present. Antennæ of six segments and with rather prominent hairs. Cornicles on somewhat shallow hairy cones. Fore wings with the radial sector short and straight; stigma elongate; media once branched. Labium lance-like.

Type (by suspension of rules), *fasciatus* Burm.

Genus DILACHNUS Baker.

Plate II, A-C.

- 1919. *Wilsonia* Baker, Can. Ent., v. 51, p. 212.
- 1919. *Dilachnus* Baker, Can. Ent., v. 51, p. 253.

Characters.—Eyes with distinct ocular tubercles. Antennæ of six segments and armed with slender hairs and circular sensoria. Cornicles on rather broad hairy cones. Fore wings with radial sector straight, media twice branched; hind wings with both media and cubitus present.

Type (fixed by Baker, 1919), *Lachniella gracilis* Wlson.

Genus SCHIZOLACHNUS Mordwilko.

Plate II, D.

- 1908. *Schizolachnus* Mordwilko, Ann. Mus. Zool. l'Acad. Imp. des Sci., St. Petersbourg, v. 13, p. 375.

The genus *Schizolachnus* was erected by Mordwilko with *tomentosus* De Geer (*pineti* Fab.) as type.

Characters.—Eyes large and with ocular tubercles present. Antennæ of six segments and with rather prominent hairs. Cornicles on somewhat shallow hairy cones. Fore wings with the radial sector straight; stigma elongate; media once branched. Labium obtuse.

Type (fixed by Mordwilko, 1908), *Aphis tomentosus* De Geer.

Genus UNILACHNUS Wilson.

Plate II, E-G.

1919. *Unilachnus* Wilson, Ent. News, v. 30, p. 5.

The genus *Unilachnus* Wilson appears to be a connecting link between this subtribe and the *Eulachnina*. In some respects the genus is very suggestive of that subtribe. The form is elongate and the cornicles are reduced. They are armed, however, with hairs and are not so reduced as in the *Eulachnina*. The ocular tubercles here are very rudimentary, almost absent, and in this regard, too, the genus suggests the *Eulachnina*, but it seems to belong in this subtribe.

Characters.—Form elongate; cornicles somewhat reduced; ocular tubercles small; media of fore wings simple. Antennæ of six segments moderately armed.

Type, *Lachnus parvus* Wilson.

Subtribe PTEROCHLORINA.

The genera belonging in the subtribe *Pterochlorina* are in some ways more primitive than those of the *Lachnina*, but in other respects some of them are more specialized. The radial sector of the fore wings is still curved and in some genera quite elongate. This is much nearer the early type of wing than is the wing of the *Lachnina* where the radial sector is short and has migrated almost to the tip of the wing. Of course, the distinct curving of this vein found in some of the genera is an advance on the slightly curved elongate vein usually met with in the fossils, but to our mind the location and character of this vein are much more primitive than in the *Lachnina*. The stigmal area and the sexual forms appear considerably more primitive than in the *Anoecina*, the specialization of which has been in a different direction from that of the *Lachnina*. The male of *Stomaphis* is, however, an exception.

Characters.—Head often divided; antennæ of six segments, armed with hairs and subcircular sensoria. Fore wings with radial sector somewhat curved and not close to the tip of the wing. Cornicles on broad hairy cones. Males usually winged.

KEY TO THE GENERA OF THE PTEROCHLORINA.

1. Stigma extending along costal margin almost to the tip of the wing.. *Longistigma*.
Stigma not so extending.....2.
2. Beak extremely long, very much longer than body; antennæ covered
with very fine, short hairs.....*Stomaphis*.
Beak normal in length; antennæ with rather stout hairs, often quite
long.....*Pterochlorus*.

Genus LONGISTIGMA Wilson.

Plate II, H-L.

1909. *Longistigma* Wilson, Can. Ent., v. 41, p. 385.

1909. *Davisia* Del Guercio, Redia, v. 5, p. 185.

The genus *Longistigma* Wilson can be distinguished at once by the shape of the stigma which is drawn out at the tip to an acute point which extends almost to the tip of the wing. The type species is

very large, one of the largest aphids. Del Guercio set no type for his subgenus which was published shortly after Wilson's. Wilson placed this species as a synonym of *caryae* Harris which he made the type of *Longistigma*.

Characters.—Size large. Head somewhat divided. Eyes large, with distinct ocular tubercles. Antennæ of six segments, armed with subcircular sensoria and prominent hairs. Fore wings with media twice branched, radial sector not a great way from the tip of wing and stigma extending around almost to tip; hind wings with both media and cubitus present. Cornicles on broad, shallow, hairy cones. Cauda and anal plate somewhat rounded.

Oviparous female apterous. Males winged.

Type (monotypic), *Aphis caryae* Harris.

Genus *PTEROCHLORUS* Rondani.

Plate II, S-X.

1848. *Pterochlorus* Rondani, "Familia Hemipterorum Aphidinae" in *Nuovi Annali delle Scienze Naturali*, p. 35.
 1855. *Dryobius* Koch, *Die Pflanzenläuse Aphiden*, p. 225.
 1908. *Tuberolachnus* Mordwilko, *Ann. Mus. Zool. de l'Acad. Imp. des Sci. St. Petersburg*, v. 13, p. 374.
 1909. *Dryaphis* Del Guercio, *Redia*, v. 5, p. 262.
 1913. *Schizodryobius* Van der Goot, *Tidj. voor Ent.*, v. 56, p. 130.
 1917. *Pterochlorides* Archangelsky, *Turkestan Ent. Stn. Rept. Tashkent*.
 1918. *Tuberodryobius* Das, *Mem. Ind. Mus.*, v. 6, p. 259.

The generic name *Cinaria* was used for *Aphis pini* L?, and *Aphis roboris* L. with *A. pini* as type. In the writer's opinion *Cinaria* can not be used now with *roboris* as type. *Roboris* was used as the type of *Dryobius*, therefore this name is clear. *Dryaphis* was used with *Pterochlorus* as a synonym but the name as a generic name was really first used by Del Guercio in 1909. *Tuberolachnus* was erected in 1908 with *viminalis* Boyer as type but the difference in the abdominal tubercle is not, in the writer's opinion, sufficient for a distinction. Van der Goot's genus is plainly a synonym. The other two generic names listed were used with *Lachnus persicae* Chol. as type. This species has several abdominal dorsal tubercles but for the same reason as *Tuberolachnus* is held to be a synonym.

Characters.—Head somewhat rounded. Antennæ of six segments, armed with subcircular sensoria and prominent hairs. Fore wings with radial sector distinctly curved, inserted some distance from tip; media twice branched. Hind wings with both media and cubitus present. Wings often banded or mottled, cornicles on hairy cones. Cauda and anal plate rounded. Abdomen sometimes with dorsal tubercles.

Type (fixed by Rondani, 1848), *Aphis roboris* Fab. (= *roboris* L.).

Genus *STOMAPHIS* Walker.

Plate II, M-R.

1870. *Stomaphis* Walker, *The Zoologist*, v. 28, p. 2000.
 1881. *Rhynchocles* Altum, *Forst Zool.*, v. 3, p. 356.

Of the five species originally in the genus *Lachnus* the species *quercus* Linn. was removed by Walker as the type of his genus *Stomaphis*. Little confusion has arisen in regard to this species. Altum's genus was erected for *Rhynchocles longirostris*.

Characters.—Head slightly rounded; eyes large with distinct ocular tubercles. Antennæ of six segments armed with large subcircular sensoria and thickly covered with fine hairs. Cornicles situated on very broad, shallow, hairy cones. Cauda subconical, slightly rounded. Anal plate rounded. Fore wings with radial sector rather long and somewhat curved. Media twice branched; hind wings with both media and cubitus present, quite widely separated. Beak very long, much longer than body. Males wingless and with rudimentary mouth parts.

Type (fixed by Walker, 1870), *Aphis quercus* Linn.

Subtribe TRAMINA.

The subtribe Tramina is composed of insects quite specialized in nature, subterranean and often associated with ants. The typical genus *Trama* is the most specialized of all and is in some characters suggestive of the *Fordina*. Its relations with the other *Lachnini*, however, are shown clearly by the other genera. The genus *Trama*, as described by Del Guercio (*Redia*, v. 5) possesses small cornicles. Specimens of *troglydites*, however, received from Schouteden, Mordwilko, and others lack cornicles entirely. Some other forms possess them either as very small cones or as large *Lachnus*-like structures. These latter are evidently the most primitive and to these is given the name *Protrama*. The insects with small cornicles are grouped under the name *Neotrama*. The genera may be separated as follows:

KEY TO THE GENERA OF THE TRAMINA.

1. Apterous form entirely without cornicles and with rudimentary eyes..... *Trama*.
 Apterous form with cornicles..... 2.
2. Apterous form with large, broad, *Lachnus*-like cornicles and large distinct compound eyes..... *Protrama*.
 Apterous form with small cone-like cornicles armed with a few hairs and more or less rudimentary eyes..... *Neotrama*.

Genus PROTRAMA, n. gen.

Plate III, P-T.

Head divided, front straight, eyes prominent and set off from the head. Antennæ of six segments armed with hairs and small subcircular protruding sensoria. Cornicles situated on broad, low, hairy cones. Cauda and anal plate rounded. Hind tarsi extremely elongate. Wing venation faint; fore wings with the media twice branched; hind wings with both media and cubitus present.

Type, *Trama radiceis* Kalt.

Genus TRAMA, Heyden.

Plate III, N.

1837. *Trama* Heyden, Mus. Senkb., v. 2, p. 293.

Head divided but not prominently so, front straight. Apterous form with the eyes reduced to a few facets. Antennæ of six segments; cornicles absent; cauda subconical, rounded. Anal plate rounded. Entire insect minutely hairy.

Type (monotypical), *Trama troglodytes* Heyden.

Genus *NEOTRAMA*, n. gen.

Plate III, M, O.

Head somewhat flat. In the apterous form the eyes reduced; antennae of six segments and the cornicles on very small cones with a few scattered hairs. Cauda subconical, rounded. Anal plate rounded. Entire body covered with fine hairs. Hind tarsi greatly elongate.

Type, *Trama troglodytes* Del Guercio (= *Neotrama delguercioi* Baker).

Tribe **THELAXINI.**

It has been the custom of most writers to place the Thelaxini (Vacuini) in the Eriosomatinae, often possibly because of the fact that only one egg is laid by the oviparous female. But the female is quite different in structure from the beakless females of the Eriosomatinae and the other forms are very different indeed.

With the Hormaphidinae there are more resemblances, the most striking of which is the structure of the thorax. The mesothorax indicates very faintly the lobes so prominent in most forms. The presence of distinct cornicles, however, is very different from the forms in the Hormaphidinae lacking these although possessing a somewhat similar thorax.

The sensory structures, too, are widely different, being similar to those found in the Phyllaphidina. Indeed, the antennae are very like those of that subtribe. The oviparous forms of the Phyllaphidina, however, lay several eggs and may be either winged or apterous and the males, though sometimes apterous, are usually winged. The venation of the Thelaxini is more reduced than in the Phyllaphidina. Taking all of these facts into consideration it seems evident that the Thelaxini should be placed in the Aphidinae and somewhat related to the Phyllaphidina, a subtribe which belongs in the Callipterini. It is evident, however, that the Thelaxini must stand somewhat apart; it is placed, therefore, as a tribe of the subfamily Aphidinae next to the Callipterini. In this tribe the specialization of the ovipara has advanced beyond that of the Callipterini in that only one egg is laid, but according to Buckton several eggs may be laid and the distinct beak is evidence of relationship.

Characters.—Cornicles present as chitinated rings on shallow hairy cones. Antennae somewhat setose, with oval or subcircular sensoria. Cauda somewhat semicircular or distinctly knobbed. Body usually armed with hairs or stout spines.

Sexual forms small and apterous, possessing beaks; oviparous female as a rule laying only one egg.

Forms living free upon the foliage.

The genera may be separated by the following key:

KEY TO THE GENERA OF THE THELAXINI.

- | | |
|--|-----------|
| Cauda distinctly knobbed..... | Thelaxes. |
| Cauda not knobbed but somewhat semicircular..... | Glyphina. |

Genus GLYPHINA Koch.

Plate III, G-L

1857. *Glyphina* Koch, Die Pflanzenläuse Aphiden, p. 259.1911. *Travaresilla* Del Guercio, Redia, v. 7, p. 299.

Characters.—Cornicles present as somewhat elevated rings. Antennæ 5-segmented, minutely setose, armed with a few stout hairs and somewhat subcircular sensoria. Fore wings with the media once branched; hind wings with only the media present. Cauda not knobbed, somewhat rounded, anal plate rounded. Body covered with hairs.

Forms living upon the foliage of plants.

Type (monotypical), *Glyphina betulæ* Kalt.

Genus THELAXES Westw.

Plate III, A-F.

Vacuna of authors, not Heyden.

1840. *Thelaxes* Westw., Int. Mod. Class. Ins. Synopsis, v. 2, p. 118.

In 1837, Heyden erected his genus *Vacuna* based on *coccinea* Heyden. He definitely stated that he thought *Phylloxera* Boyer was the same genus. Kaltenbach stated that *coccinea* is a *Phylloxera* and so considered *dryophila* as type of *Vacuna*, as this species was included in the genus by Heyden. On the authority of Schouteden and other European workers *coccinea* is now considered a *Phylloxera* and another type, *dryophila*, can not be set for the genus in order to apply *Vacuna* to the genus as now understood. *Vacuna* with *coccinea* as type will become a synonym of *Phylloxera* and another name will be necessary to apply to the genus having *dryophila* as type. The next name used appears to be *Thelaxes* Westwood.

Characters.—Cornicles present as chitinized rings on broad low cones. Antennæ of the stem mother 5-segmented. Alate form with 3-segmented antennæ, sensoria oval or subcircular. Fore wings with the media once branched, hind wings with the cubitus lacking. Cauda distinctly knobbed, anal plate rounded. Sexual forms small and apterous, possessing distinct beaks and feeding; oviparous female producing normally but one egg.

Type (fixed by Westwood, 1840), *Thelaxes quercicola* Westw. (= *Aphis dryophila* Schr.)

Tribe CALLIPTERINI.

The tribe Callipterini is composed of forms which live upon the foliage of plants. The species in many of the subtribes have developed peculiar habits. Some forms are almost solitary whereas others live in colonies. Some have developed the power of leaping, while others are sedentary. The sexual forms do not vary greatly from the viviparous forms. In nearly all of the subtribes the males are winged, though in the Saltusaphidina they are apterous. In the other tribes intermediate males may occur in the same species with alate males. The oviparous females are nearly always apterous, although in the Phyllaphidina alate ovipara may occur. Both sexes feed and the ovaries of the oviparous female are developed so that several eggs are laid.

The wing veins are not reduced in most species. In some, however, the radial sector of the fore wings is very faint or entirely absent. This condition is met with in several genera of the Callipterina. That it is this vein which is lacking is indicated by the trachea of the freshly emerged wing. Here the media is represented by M_1 , M_2 , and M_{3+4} . The cubitus and first anal are distinct tracheæ, whereas the second anal is faintly indicated. In the hindwing besides the radial sector three oblique tracheæ are present; these are the media, cubitus, and first anal. Only the media and cubitus are represented in the venation.

Considerable variation is met with in the cornicles of this tribe but they are never long and prominent as in the Aphidini. The usual form is the truncate one represented in *Myzocallis*, *Chaitophorus*, etc. Very often the cornicles are sculptured. In some cases they are reduced to small cup-shaped structures and in others they are represented by mere rings.

The antennæ, as a rule, are long and slender and armed with few sensoria. These sensoria are usually small, subcircular or oval. In rare cases they are somewhat elongate.

The cauda in this tribe is as a rule knobbed and the anal plate bilobed. In some cases, however, the cauda and anal plate are both rounded. In the *Saltusaphidina* the anal plate is divided and the cauda remains distinctly knobbed.

Wax secretion is present to a limited extent in this tribe. It is most developed in the *Phyllaphidina*. Here there are large lateral abdominal wax plates in all of the forms and the insects present a wool-like appearance on the foliage. In the genus *Eucraphis* wax secretion is found to a limited extent. In one species, *mucidus* Fitch, it is, however, abundant and the insects of this species often seem to float in the air, a peculiar appearance common also in the *Eriosomatinae*. In the *Saltusaphidina* also distinct wax plates occur, particularly in the oviparous forms. These are arranged along the abdominal segments.

The habit of leaping is common in the *Saltusaphidina* as the name implies. Here the muscles of the femora are greatly enlarged for this purpose. Many of the other members of the tribe approach this condition, especially in the genus *Monellia*. Others, although they do not distinctly leap, drop so suddenly when disturbed that they almost appear to leap from the foliage. Our common *Symydobius* on the birch is difficult to collect on account of such a habit and other forms of *Callipterina* are very similar in action. Certain species in this tribe are closely attended by ants in return for the honeydew excreted. Some species are protected by these Hymenoptera by means of sheds or roofs built over colonies on the leaves or twigs. These sheds are found quite commonly upon the leaves of the oaks protecting the spe-

cies described as *Symydobius albasiphus* by Davis and here placed as *Neosymydobius*.

The internal structure of insects of this tribe appears not to differ markedly from the structure in other groups. Witlaczil, however, has reported that in certain members of this tribe the intestine forms a closed loop almost similar to that found in the Chermidae.

As a rule, in this tribe, the various forms met with in the subfamily occur. In the genus *Monellia*, however, in some species at least, apterous viviparous forms seldom occur, nearly all the viviparous forms being alate.

The subtribes may be separated by the following key:

KEY TO THE SUBTRIBES OF THE CALLIPTERINI.

1. Eyes with ocular tubercles present, head not elongate..... 2.
Eyes without ocular tubercles present, head often elongate..... SALTUSAPHIDINA.
2. Antennæ armed with rather long, prominent hairs..... 3.
Antennæ usually only with minute, sometimes stout bristles..... 5.
3. Cornicles absent..... FULLAWAYINA.
Cornicles present..... 4.
4. Cornicles cylindrical or vasiform..... PTEROCOMMINA.
Cornicles truncate, enlarged at base..... CHAITOPHORINA.
5. Cornicles absent above..... MONAPHIDINA.
Cornicles present, position as usual..... 6.
6. Cornicles reduced to mere rings; large lateral abdominal wax plates present..... PHYLLAPHIDINA.
Cornicles usually not reduced to mere rings; no large abdominal wax plates present..... 7.
7. Cornicles variable, often long and somewhat swollen; oviparous female with an elongate ovipositor..... DREPANAPHIDINA.
Cornicles never long; always short and truncate; oviparous female not always with an elongate ovipositor..... CALLIPTERINA.

Subtribe PHYLLAPHIDINA.

The subtribe Phyllaphidina is erected for the species related to the genus *Phyllaphis*. Many of the characters show these species as quite closely related to the Callipterina, while in other ways they very strongly suggest the Thelaxini, as indicated under the discussion of the tribe.

Characters.—Cornicles present; antennæ of six segments, minutely setose, sensoria elongate or subcircular; cauda knobbed or rounded, anal plate often bilobed, wax glands present. Forms living free or in pseudogalls. Sexual forms often alate, sometimes, however, apterous or intermediate, showing that the apterous condition has developed but recently; oviparous female producing several eggs.

KEY TO THE GENERA OF THE PHYLLAPHIDINI.

1. Anal plate deeply cleft and U-shaped..... Shivaphis.
Anal plate entire or somewhat bilobed, not deeply cleft..... 2.
2. Cauda rounded, anal plate entire..... 3.
Cauda knobbed, anal plate somewhat bilobed..... Phyllaphis.
3. Oviparous females with annular sensoria..... Neophyllaphis.
Oviparous females with small transverse sensoria..... Tamalia.

Genus **NEOPHYLLAPHIS** Takahashi.1920. *Neophyllaphis* Takahashi, Can. Ent., v. 52, p. 20.

Characters.—Cornicles slightly elevated. Antennæ of six segments, with narrow, transverse sensoria. Fore wings with media twice branched, hind wings with both media and cubitus present. Cauda and anal plate rounded, cauda sometimes slightly constricted. Oviparous females winged and possessing annular sensoria. Forms wax secreting and living free on the plants.

Type (monotypical), *Neophyllaphis podocarpi* Takahashi.Genus **PHYLLAPHIS** Koch.

Plate IV, FF, GG.

1857. *Phyllaphis* Koch, Die Pflanzenläuse Aphiden, p. 248.

The well-known genus *Phyllaphis* Koch is represented by *fagi* L., but as indicated under *Tamalia* has been made to include species of somewhat different structure.

Characters.—Cornicles present as chitinized rings which are very slightly elevated on low conical bases. Antennæ of six segments, long and slender, minutely setose, sensoria narrowly oval. Fore wings with the media twice branched; hind wings with both media and cubitus faintly indicated. Cauda knobbed, anal plate slightly divided.

Forms living upon the foliage, sometimes producing a curling of the leaves. Males usually winged; oviparous form apterous, producing several eggs.

Type (monotypical), *Aphis fagi* L.Genus **TAMALIA** n. gen.

Plate IV, HH, II.

The genus *Tamalia* Baker is erected for *Pemphigus coweni* Ckll., a species which has since been placed in *Phyllaphis*. It is, however, quite distinct from the type of the genus and undoubtedly represents a new genus. Mr. Theodore Pergande received this species, *coweni*, from California and made some notes on the material, thinking, however, that it was a new species. He gave it a provisional name and the new generic name here used. This name, as far as our knowledge goes, never was published. Among the large number of new genera conceived by Pergande this is one of the few valid ones and his manuscript name, therefore, is used here.

Characters.—Cornicles present as mere flanges on low, broad, conical bases. Antennæ of six segments minutely setose and with narrow sensoria. Fore wings with media once branched, hind wings with both media and cubitus present. Cauda and anal plate both rounded. Abdominal wax plates present.

Forms living in pseudogalls. Sexes sometimes both winged, oviparous form producing several eggs.

Type, *Pemphigus coweni* Ckll.Genus **SHIVAPHIS** Das.1918. *Shivaphis* Das, Mem. Ind. Mus., vol. 6, p. 245.

The genus *Shivaphis* was erected with *celti* Das as type, and *celti* is evidently the species redescribed as *Chromaphis celticolens* by Essig.¹

¹ ESSIG, E. O., and KUWANA, S. I. Some Japanese Aphididae. In Proc. Cal. Acad. Sci., v. 8, no. 3, p. 95, 1918.

The writer has studied a series of specimens of this species taken in 1907 on *Celtis sinensis*. There seems little doubt that the genus is related to *Phyllaphis*. The dorsal wax glands are of much the same structure as those found in *fagi* L. The deeply cleft anal plate, however, at once separates the two. The cauda which is almost cylindrical in some specimens is quite distinctly knobbed in others.

Characters.—Cornicles present as mere rings. Head without prominent antennal tubercles. Antennæ of six segments, sensoria elliptical. Fore wings with the media twice branched, hind wings with both media and cubitus present. Cauda cylindrical or knobbed. Anal plate deeply divided. Males winged. Oviparous females apterous. Rows of wax glands present.

Type (monotypical), *Shivaphis celti* Das.

Subtribe CALLIPTERINA.

The subtribe Callipterina is a somewhat large and interesting one. Some of the species are very large and more or less solitary, others are small and live in colonies. In some genera apterous viviparous forms, with the exception of the stem mother, seldom occur, while in other genera they are as a rule, present. The males are in most cases alate and the oviparous forms apterous. The species of nearly all the genera live upon the leaves of plants. They do not affect these greatly, as a rule, although when abundant the insects often seriously interfere with the proper development of the trees attacked. Many of the insects are armed upon their bodies with prominent spines or tubercles.

Characters.—Cornicles present, truncate in form. Antennæ with setæ or spines, of six segments, and armed with subciroular or in a few cases somewhat elongate sensoria. Wings often clouded, mottled, or banded. Cauda as a rule knobbed, anal plate usually more or less indented or bilobed. Body often armed with capitate spines or tubercles.

KEY TO THE GENERA OF THE CALLIPTERINA.

1. Cauda distinctly knobbed, anal plate usually bilobed or sometimes deeply divided 3.
- Cauda not distinctly knobbed, anal plate entire or almost so 2.
2. Antennæ minutely setose, sensorium at base of unguis oval or somewhat rounded; oviparous female with secondary sensoria *Symydobius*.
- Antennæ not minutely setose, sensorium at base of unguis long and narrow, oviparous female without secondary sensoria *Eucraphis*.
3. Anal plate deeply divided with a U-shaped cleft so that the lobes appear as distinct; cauda knobbed *Therioaphis*.
- Anal plate bilobed, not deeply divided; cauda very markedly knobbed... 4.
4. Antennæ and often the cornicles with prominent hairs *Callipterus*.
- Cornicles and antennæ without such hairs 5.
5. Cornicles much reduced; wings sometimes horizontal in repose *Monellia*.
- Cornicles truncate, fairly well developed; wings not horizontal in repose... 6.

6. More or less distinct antennal tubercles present; oviparous female with secondary sensoria.....Calaphis.
 No distinct antennal tubercles present; oviparous female without secondary sensoria..... 7.
 7. Anal plate slightly indented, sometimes almost entire; no apterous viviparous forms developed.....Chromaphis.
 Anal plate distinctly bilobed; apterous viviparous forms common....Myzocallis.

Genus CALAPHIS Walsh.

Plate IV, S, U.

1863. *Calaphis* Walsh, Proc. Ent. Soc. Phila., v. 1, p. 301.1913. *Siphonocallis* Del Guercio, Redia, v. 9, p. 293.1913. *Callipterinella* Van der Goot, Tijdschr. voor Ent., v. 56, p. 118.

Walsh erected his genus *Calaphis* for his *betulella*, a species which lacks the radial sector in the wing, and on this character he based his genus. Del Guercio based his *Siphonocallis* on *betulaecolens* Fitch, distinguishing it from his conception of the genus *Callipterus*, which conception, however, was not according to type. A study of *betulaecolens* shows that in all respects, with the exception of the radial sector, this species is similar to *betulella*. Many specimens of *betulaecolens* lack the radial sector and in most cases it is only faintly indicated at best. These two species, therefore, are probably congeneric.

The genus *Callipterinella* was based on *betularius* Kalt., and this species proves to be very similar to *betulaecolens*. It is true that the frontal tubercles are not prominent in this species as they are in the type of *Calaphis*. There seems no doubt, however, that all of these three species are closely related. This relation is shown in part by the sexual forms. The oviparous females all possess sensoria on the antennæ and are very similar in other body characters. This presence of sensoria in the oviparous form, while not important in some groups, separates quite distinctly this small group of species from those of the *Myzocallis* type. It seems evident that the relations of *betularius* are with *betulaecolens* and *betulella*. *Callipterinella*, therefore, is also a synonym.

Characters.—Cornicles present, distinct, truncate. Antennæ of six segments, armed with oval sensoria and placed on more or less distinct tubercles. Fore wings with the media twice branched, the radial sector either absent or faintly indicated, sometimes, however, complete; hind wings with both media and cubitus present. Cauda distinctly knobbed, anal plate bilobed, body with prominent hairs.

Forms living more or less solitary upon the foliage, sexes not markedly different from the other forms; oviparous female producing several eggs and possessing sensoria upon the antennæ.

Type (monotypical), *Calaphis betulella* Walsh.

Genus *CALLIPTERUS* Koch.

Plate IV, I, J.

1855. *Callipterus* Koch, Die Pflanzenläuse Aphiden, p. 208.
 1870. *Callaphis* Walker, The Zoologist, v. 5, p. 2000.
 1881. *Ptychodes* Buckton, Mon. British Aphids, v. 3, p. 39.
 1904. *Panaphis* Kirkaldy, The Entomologist, v. 37, p. 279.
 1917. *Nippocallis* Matsumura, Jour. Coll. Agr. Tohoku Univ., v. 7, pt. 6, p. 365.

In erecting the genus *Callipterus*, Koch included a number of species among which was *juglandis* Kalt. In 1860, Passerini set *juglandis* as the type of *Callipterus* and erected his *Myzocallis* for species similar to *coryli* Goetz.

Most writers overlooked Passerini's work and considered the genus *Callipterus* in the light of *Myzocallis*. This is the conception commonly held by many to-day. The application of *Callipterus*, however, must be restricted to species essentially like *juglandis*. All the other generic names listed as synonyms were, with one exception, used with this same species *juglandis* as type and therefore require little comment.

The genus *Nippocallis* was erected with *kuricola* Mats. as type. Specimens of this species studied by the writer are not in good condition for the observation of the anal plate. All the characters visible, however, indicate that this species is a *Callipterus*.

Characters.—Cornicles present, truncate in form, rather prominent and often armed with long hairs. Antennæ of six segments, armed with stout hairs, sensoria usually oval. Fore wings with the media twice branched, hind wings with both cubitus and media present. Veins usually bordered. Radial sector often faintly indicated. Cauda not distinctly knobbed in all cases. Anal plate bilobed; body usually covered with prominent hairs.

Forms living free upon the foliage. Sexual forms not differing markedly from the other forms, oviparous female producing several eggs.

Type (fixed by Passerini, 1860), *Aphis juglandis* Frisch.

Genus *CHROMAPHIS* Walker.

Plate IV, O, P.

1870. *Chromaphis* Walker, The Zoologist, v. 5, p. 2001.

The genus *Chromaphis* was erected with *juglandicola* Kalt. as type. It is related quite closely to *Monellia*.

Characters.—Cornicles moderate in size, somewhat flanged. Antennæ of seven segments armed with oval sensoria. Fore wings with the media twice branched, hind wings with media and cubitus present, wings not held horizontally in repose. Cauda knobbed, anal plate slightly indented. Sexual forms somewhat similar to the viviparous ones. Males usually winged. Oviparous female with the ovaries developed normally, laying numerous eggs.¹

Forms living free upon the foliage usually all summer; viviparous generations winged.

Type (monotypical), *Aphis juglandicola* Kalt.

¹ Davidson believes as many as 30 may be produced by one female.

Genus *THERIOAPHIS* Walker.

Plate IV, K, L.

1870. *Therioaphis* Walker, The Zoologist, p. 1999.
 1905. *Kallistaphis* Kirkaldy, Can. Ent., v. 37, p. 417.
 1906. *Eucallipterus* Schouteden, Ann. Ent. Soc. Belg., v. 50, p. 31.¹
 1915. *Neocallipterus* Van der Goot, Beiträge zur Kennt. der Holl. Blattläuse, p. 320.

The genus *Therioaphis* Walker was erected with *ononidis* Kalt. as type, and *ononidis* has been shown by Theobald to be the common "yellow clover aphid," *trifolii* of Monell. This species has a deeply cleft anal plate quite different from that of *Myzocallis*. *Eucallipterus* was erected with *tiliae* L. as type, a species with quite similar structure. *Eucallipterus*, therefore, will become a synonym. *Betulicola* Kalt. has been used as type by Kirkaldy and Van der Goot. According to Das, Van der Goot considers this congeneric with *trifolii*. Therefore *Therioaphis* is the name that must be used.

Characters.—Cornicles truncate, rather constricted mesad of apex. Antennæ of six segments without prominent hairs and armed with subcircular sensoria. Fore wings with media twice branched; hind wings with both media and cubitus present. Wings often variously marked. Prothorax rather elongate; cauda knobbed. Anal plate deeply bifid so that two long, narrow lobes are formed. Body often with prominent hairs.

Type (monotypical), *Aphis ononidis* Kalt.

Genus *EUCERAPHIS* Walker.

Plate IV, Q, R.

1870. *Euceraphis* Walker, The Zoologist, p. 2001.
 1908. *Callipteroides* Mordwilko, Ann. Mus. Zool. l'Acad. Imp. des Sci. St. Petersburg, v. 13, p. 377.
 1913. *Callipteroides* Van der Goot, Tijds. voor. Ent., v. 56, p. 151.

When Walker erected his genus *Euceraphis* with *betulae* L. as type he had in mind evidently the same species as that described by Koch under the same specific name, and thus separated species of this type. Mordwilko in 1900 erected the genus *Callipteroides* with *nigritarsus* Heyden as type. Specimens of this species received from Mordwilko show that the species he had was the *betulae* of Koch or at least a species very close to it. This would then make *Callipteroides* a synonym of *Euceraphis*. In 1913 Van der Goot used the name *Callipteroides* with *betulae* Koch as type and his placing, therefore, should be under *Euceraphis*.

Characters.—Cornicles present, truncate. Antennæ of six segments, long and slender, armed with rather narrow sensoria usually near the base of segment III, the unguis of segment VI usually not much longer than the base, sensorium at the base of unguis long, oval, and fringed; more or less distinct frontal tubercles present. Fore wings with the media twice branched, hind wings with both media and cubitus present. Cauda usually knobbed and rather large. Anal plate usually entire. Abdomen of the alate form often with distinct wax-producing glands. Forms very large and usually solitary in habit, sexes similar to the other forms; oviparous female producing several eggs. Type (fixed by Walker, 1870), *Aphis betulae* (L.) Walker (= *Callipterus betulae* Koch).

¹ There is considerable evidence for keeping this genus distinct.

Genus *MONELLIA* Oestlund.

Plate IV, M, N.

1887. *Monellia* Oestlund, Geol. and Nat. Hist. Survey Minu., Bul. no. 4, p. 44.

The genus *Monellia* Oestlund was erected for *caryellus* Fitch and only one species was included in the genus at the time. Several other species, however, were made synonyms of *caryellus* which are quite different from that species and fall into other genera.

Characters.—Cornicles present as mere rings; antennæ slender, of six segments; sensoria oval or subcircular; head broad for its length; prothorax prominently separated from the mesothorax. Fore wings with the media twice branched; hind wings with both media and cubitus present. Wings often held flat upon the back, cauda knobbed, anal plate bilobed. Forms living solitary upon the leaves, sometimes having the power of leaping. Apterous forms rare. Sexes feeding; oviparous female laying several eggs.

Type (monotypical), *Aphis caryella* Fitch.Genus *MYZOCALLIS* Pass.

Plate IV, G, H.

1860. *Myzocallis* Passerini, Gli Afidi, p. 28.1860. *Pterocallis* Passerini, Gli Afidi, p. 28.1894. *Subcallipterus* Mordwilko, Varshava Univ. Izvestiia, v. 8, no. 58, p. 53.1894. *Tuberculatus* Mordwilko, Varshava Univ. Izvestiia, v. 8, no. 58, p. 60.1913. *Callipterus* Van der Goot, Tijd. voor Ent., v. 56, p. 116.1915. *Tuberculoides* Van der Goot, Beiträge zur Kennt. der Holl. Blattläuse, p. 313.1917. *Acanthocallis* Matsumura, Jour. Coll. Agr. Tohoku Univ., v. 7, pt. 6, p. 368.1917. *Takecallis* Matsumura, Jour. Coll. Agr. Tohoku Univ., v. 7, pt. 6, p. 373.

When Passerini erected the genus *Myzocallis* in 1860 he placed *coryli* Goetz as type. Later in the same work he erected his genus *Pterocallis* with *alni* Pass. as type. This species proves to be very similar indeed to *coryli*, so similar in most of the characters that the writer believes the genus *Pterocallis* to be a synonym of *Myzocallis*. The type of the genus, *coryli* Goetz, was also placed as the type of *Callipterus* by Van der Goot, in 1913, in spite of the fact that another type for that genus had been set in 1860. *Callipterus* Van der Goot (1913) is therefore a synonym of *Myzocallis*. The species *alni* Pass. is universally considered the same species as *alni* Fab., and this species was made the type of the genus *Subcallipterus* by Mordwilko in 1894. *Subcallipterus* Mordwilko, 1894, is therefore a synonym of *Myzocallis* for the same reason as is *Pterocallis* Pass., 1860. The species *quercus* Kalt. was made the type of the *Tuberculatus* by Mordwilko in 1894, but this species seems too closely related to *coryli*. *Tuberculatus*, therefore, becomes a synonym. The species *quercus* Kalt. was made the type of *Tuberculoides* by Van der Goot, 1915, and this is quite typically a *Myzocallis*. A number of genera have been erected by Matsumura which are so very little different from the type species that they are listed here as synonyms. This author follows the idea of proportions of the antennal segments as generic characters.

Characters.—Cornicles truncate without a very distinct neck; antennæ of six segments armed with a few minute bristles and oval or subcircular sensoria. Fore wings with the media twice branched; hind wings with both media and cubitus present. Cauda knobbed; anal plate bilobed, not divided; body usually with stout hairs.

Type (fixed by Passerini, 1860), *Aphis coryli* Goetz.

Genus **SYMDOBIUS** Mordwilko.

Plate IV, DD, EE.

1894. *Symydobius* Mordwilko, Varshava Universitetskii Izvestiia, v. 8, no. 58, p. 65.

1917. *Yezocallis* Matsumura, Jour. Coll. Agr. Tohoku Univ., v. 7, pt. 6, p. 369.

Symydobius of later authors.

The genus *Symydobius* Mord., which was erected for *oblongus* Heyden, has often been spelled *Symdobius* by subsequent writers. This is probably due to the erection of the genus in a Russian publication which is available to few workers, at least in this country. Specimens of this species studied were collected by Mordwilko at Petrograd and Warsaw and by Schouteden at Brussels. The species which passes under the name of *oblongus* in America is quite distinct, as has been pointed out by the writer.

Characters.—Cornicles present, truncate or with an evident neck and on a broad low base. Antennæ of six segments armed with numerous delicate hairs, sensoria somewhat oval or subcircular; sensorium at the base of the unguis not long and narrow, with a fringe but without a prominent one, cauda semicircular, anal plate similar in shape, sometimes slightly indented. Fore wings with the media twice forked; hind wings with both media and cubitus present, somewhat separated at the base.

Type (monotypical), *Aphis oblonga* Heyden.

Subtribe **SALTUSAPHIDINA.**

The subtribe *Saltusaphidina* is separated from the other related ones principally on the nature of the head. The most important character, possibly, is the structure of the eyes, in which the ocular tubercles appear to be wholly lacking.

Characters.—Forms living usually in damp places upon the foliage of sedges and grasses, narrow elongate bodies, eyes with ocular tubercles lacking, legs often modified for leaping. Oviparous forms apterous, somewhat similar to the viviparous forms, producing several eggs.

KEY TO THE GENERA OF THE SALTUSAPHIDINA.

Head considerably elongate, cornicles cup shaped, legs modified for leaping.....	<i>Saltusaphis</i> .
Head not much elongated, cornicles mere rings, legs not modified for leaping.....	<i>Thripsaphis</i> .

Genus **THRIPSAPHIS** Gillette.

Plate IV, X.

1917. *Thripsaphis* Gillette, Can. Ent., v. 49, p. 193.

The genus *Thripsaphis* was separated from *Saltusaphis* for *balli* Gillette, which the present writer had included in that genus, and certain other similar species.

Characters.—Cornicles present as slightly elevated rings; antennæ of six segments armed with subcircular sensoria. Eyes without ocular tubercles. Fore wings with the media twice branched, hind wings with the cubitus sometimes absent, cauda knobbed, anal plate divided, body with spinelike hairs.

Forms living free upon grasses and sedges in moist localities. Sexes apterous, oviparous female producing several eggs.

Type (fixed by Gillette, 1917), *Brachycolus balli* Gill.

Genus SALTUSAPHIS Theobald.

Plate IV, V, W.

1915. *Saltusaphis* Theobald, Bull. Ent. Research, v. 6, pt. 2, p. 138.

Characters.—Cornicles present, cup-shaped or truncate; antennæ of five segments, minutely setose; sensoria small and subcircular. Head elongate, ocular tubercles absent. Fore wings with the media twice branched; hind wings with the cubitus usually absent; cauda knobbed; anal plate divided, caudal extremity of the abdomen sometimes bilobed; body covered with spines which are often modified into different shapes.

Forms living more or less solitary upon the leaves of grasses or sedges in marshy regions. Sexual forms apterous, oviparous female laying several eggs.

Type (monotypical), *Saltusaphis scirpus* Theo.

Subtribe DREPANOSIPHINA.

The subtribe Drepanosiphina is evidently related to the callipterine branch of the tribe rather than the chaitophorine one. It has specialized in the opposite direction from the Monaphidina in that the cornicles are more or less prominently developed. It would appear to bear the same relation to this branch of the tribe as does the Pterocommina to the chaitophorine one. There is considerable variation in the development of the cornicles, even within certain of the genera. Some have very large cornicles, others have small ones. They all appear, however, to have the same general structure.

Characters.—Cornicles present, varying greatly in development from very small to very large. Cauda somewhat knobbed, anal plate slightly indented. Oviparous female with a long drawn out ovipositor.

KEY TO THE GENERA OF THE DREPANOSIPHINA.

1. Cornicles extremely long and somewhat swollen in the middle.....Drepanosiphum.
Cornicles not extremely long and larger at the base.....2.
2. Cornicles very small, truncate.....Neosymydobius.
Cornicles large with a swollen region at the base.....Drepanaphis.

Genus DREPANAPHIS Del Guercio.

Plate IV, JJ-LL.

1909. *Drepanaphis* Del Guercio, Rivista di Patologia Vegetale, n. s., v. 4, no. 4, p. 49-50.

1909. *Phymatosiphum* Davis, Annals Ent. Soc. America, v. 2, p. 196.

The two generic names given were both used with the same type species, and therefore no discussion in regard to the use of the names is necessary.

Characters.—Cornicles large but not of the same shape as those of Drepanosiphum, being rather narrow toward the distal extremity and swollen at the base. Antennæ of six segments armed with subcircular or oval sensoria and a few scattered hairs. Fore wings with the media twice branched, hind wings with both media and cubitus present. Cauda knobbed, anal plate somewhat indented. Forms living more or less

solitary upon the foliage of trees. Males winged. Oviparous female with a distinct elongated ovipositor and producing several eggs.

Type (monotypical), *Drepanosiphum acerifolii* Thos.

Genus **DREPANOSIPHUM** Koch.

Plate IV, MM.

1855. *Drepanosiphum* Koch, Die Pflanzenläuse Aphiden, p. 201.

1885. Type fixation, Lichtenstein, Monographie des Aphidiens, p. 175.

Cornicles very long, quite distinctly swollen in the middle or subcylindric. Antennae of six segments with short, scattered hairs and oval or subcircular sensoria. Fore wings with the media twice branched. Hind wings with both media and cubitus present. Cauda knobbed, anal plate slightly indented.

Forms living upon the foliage of plants, males usually winged. Oviparous female with a distinct elongated ovipositor.

Type (fixed by Lichtenstein, 1885), *Aphis platanoides* Schr.

Genus **NEOSYMYDOBIUS**, n. gen.

The genus *Neosymydobius* is erected for species similar to that described as *Symydobius albasiphus* Davis. It is evident that this species is not a *Symydobius*. Members of that genus are very large and differ in several ways. We place the present genus here with considerable doubt.

Characters.—Cornicles small, truncate, Callipterus-like. Antennae of six segments which are armed with a few rather stout hairs. Fore wings with the media twice branched, hind wings with both media and cubitus present. Cauda knobbed, anal plate slightly indented. Forms living in colonies upon the foliage of trees. Body, particularly of the apterous forms, covered with rather stout spine-like hairs. Oviparous female with a long ovipositor and depositing several eggs. Males usually winged.

Type, *Symydobius albasiphus* Davis.

Subtribe **MONAPHIDINA**.

The subtribe *Monaphidina*, erected for the genus *Monaphis*, is very similar in most respects to the *Callipterina*, but lacks the cornicle dorsally. It seems evident that it is a specialization from insects of the *Callipterus* type in much the same way that *Fullawaya* is related to those of the *Chaitophorus* type. One genus only is known at present. This differs more from the *Callipterina* than does *Fullawaya* from the *Chaitophorina*.

Genus **MONAPHIS** Walker.

1870. *Monaphis* Walker, The Zoologist, p. 2001.

1891. *Bradyaphis* Mordwilko, Varshava Universitetskii Izvestiia, v. 8, p. 59.

Few remarks on the synonymy of the genus *Monaphis* Walker are necessary as the same species was used as type in both cases mentioned. The genus is a very remarkable one, being peculiar in many ways.

Characters.—Cornicles faint; antennae of six segments, without distinct hairs, sensoria small and circular; cauda somewhat rounded but with an acute point or projection; anal plate similar; fore wings with the media twice branched; hind wings with both media and cubitus present.

Type (fixed by Walker, 1870), *Aphis antennata* Kalt.

Subtribe CHAITOPHORINA.

The subtribe Chaitophorina is composed of aphids which are similar in many ways to the Callipterina. They differ in that they are always armed with long hairs which quite prominently cover the antennæ as well as the other parts of the body. Some of the species perhaps are given more to living in colonies than are the Callipterina, but this habit varies in that subtribe as well.

KEY TO THE GENERA OF THE CHAITOPHORINA.

- | | |
|--|---------------|
| 1. Cauda quite distinctly knobbed..... | 2. |
| Cauda not knobbed but rounded..... | 3. |
| 2. Antennæ of five segments..... | Sipha. |
| Antennæ of six segments..... | Chaitophorus. |
| 3. Body elongate; small dimorphic forms developed..... | Periphyllus. |
| Body not elongate; no dimorphic forms developed..... | 4. |
| 4. Antennæ of five segments..... | Atheroides. |
| Antennæ of six segments..... | 5 |
| 5. Anal plate entire or slightly indented..... | Neothomasia. |
| Anal plate divided into two quite separate parts..... | Patchia. |

Genus ATHEROIDES Haliday.

1839. *Atheroides* Haliday, Ann. and Mag. Nat. Hist., v. 2, p. 189.

More careful collecting of marsh-inhabiting species may show that this genus is a specialization from the Chaitophorina as is the Saltusaphidina from the Callipterina, for most specimens falling here seem to lack ocular tubercles.

Characters.—Antennæ of five segments armed with stout spines. Fore wings with media twice branched; hind wings with both media and cubitus present. Cornicles reduced to mere rings. Cauda broadly rounded. Form elongate and flat. Entire insect prominently spined. Species living on sedges and grasses.

Type (set by Kirkaldy, 1906), *Atheroides serrulatus* Haliday.

Genus CHAITOPHORUS Koch.

Plate IV, CC.

1854. *Chaitophorus* Koch, Die Pflanzenläuse Aphiden, p. 1.

1870. *Tranaphis* Walker, The Zoologist, p. 1999.

1870. *Arctaphis* Walker, The Zoologist, p. 2000.

1912. *Eichochaitophorus* Essig, Pom. Coll. Journ. Ent., v. 4, p. 721.

1912. *Micrella* Essig, Pom. Coll. Journ. Ent., v. 4, p. 716.

1856. Type fixation, Gerstaecker, Bericht for 1854, p. 162.

In 1854 Koch erected the genus Chaitophorus with several species. *Aphis populi* was made the type by Gerstaecker in 1856. The same species was used by Walker as type of his genus *Arctaphis* and therefore this name will become a synonym. The types of both of Essig's genera show that these vary little from *populi*. The genus *Tranaphis* was erected with *salicivorus* Walker as type and this species is similar in general characters to *populi*. Therefore, *Tranaphis* will become a synonym.

In 1860 Passerini used *aceris* L. as the type of Chaitophorus and this placing has often been followed, but that of Gerstaecker has priority.

Characters.—Cornicles present, truncate, rather prominent. Antennae of six segments, armed with subcircular sensoria and rather prominent hairs. Fore wings with the media normally twice branched, hind wings with both media and cubitus present. Cauda distinctly knobbed. Anal plate entire, sometimes somewhat indented. Sexual forms not differing markedly from the viviparous ones. Males winged, as a rule, but sometimes intermediate or apterous. Oviparous females apterous with the ovaries normally developed and producing several eggs. Both sexes feeding.

Forms living usually upon the leaves of trees; no dimorphic forms developed.

Type (fixed by Gerstaecker, 1856), *Aphis populi* L.

Genus PATCHIA, n. gen.

Characters.—Cornicles truncate; antennae of six segments, hairy and with circular sensoria. Fore wings with the media twice branched, the radial sector absent or faintly indicated; hind wings with both media and cubitus present. Cauda rounded or slightly conical; anal plate divided into two separate parts.

Type, *Patchia virginiana* Baker.

Patchia virginiana, n. sp.

Alate viviparous female.—Antennae as follows: III, 0.48 mm., with an even row of about 12 subcircular sensoria; IV, 0.288 mm.; V, 0.24 mm.; VI (0.16–0.192 mm.). Color brown with a large black patch on dorsum of abdomen and with lateral patches of same color. Wings with the radial sector absent and the veins heavily bordered. Apterous form almost solid velvety black. Both forms secreting wax.

Found on the bark of chestnut at East Falls Church, Va. The type is in the U. S. National Museum (Cat. No. 23063).

Genus PERIPHYLLUS Van der Hoeven.

Plate IV, AA, BB.

1852. *Phillophorus* Thornton, Proc. Ent. Soc. London, n. s., v. 2, p. 78.

1858. *Chelymorpha* Clark, The Microscope.

1863. *Periphyllus* Van der Hoeven, Tijds. voor Ent., v. 6, p. 7.

1913. *Chaitophorinella* Van der Goot, Tijds. voor Ent., v. 56, p. 150.

1917. *Arakawana* Matsumura, Journ. Coll. Agr. Tohoku Univ., v. 7, pt. 6, p. 375.

In 1852 Thornton used the name *Phillophorus* with his *testudinatus* as type. This name had, however, been used in 1840. Koch erected the genus Chaitophorus in 1854 and included therein a number of species. In 1856 Gerstaecker set *Aphis populi* L. as the type of Chaitophorus and therefore prevented the use of the name for species such as *testudinatus* unless all of Koch's species are included. In 1858 Clark used the name *Chelymorpha* with the specific name *phyllophora*. The species he discussed is the *testudinatus* of Thornton. The generic name *Chelymorpha*, however, was used as early as 1834 and, therefore, is not available. In 1863 Van der Hoeven employed the generic term *Periphyllus* with his species *testudo* as type. This name is a synonym of *testudinatus* Thornton, and the generic name seems to be the first one available.

In 1913 Van der Goot employed the generic name Chaitophorinella with *testudinatus* as type, and this name, therefore, will become a synonym of *Periphyllus*.

Characters.—Cornicles present, truncate in form, often sculptured. Antennae of six segments (with the exception of the dimorph) armed with oval sensoria and prominent hairs. Fore wings with the media twice branched; hind wings with both media and cubitus present. Cauda and anal plate rounded.

Forms living upon the foliage of trees. Sexes not strikingly different from the other forms, possessing beaks and feeding. Males winged, oviparous females with the ovaries normally developed, thus laying several eggs. Small lamellate or hairy dimorphic forms produced in summer.

Type (monotypical), *Periphyllus testudo* Van der Hoeven (= *testudinatus* Thorton).

Genus NEOTHOMASIA, n. n.

Plate IV, Y, Z.

1910. *Thomasia* Wilson, Can. Ent., v. 42, p. 386.

Wilson erected the genus *Thomasia* with *populicola* Thos. as type, and his description appeared in December, 1910. The same name had, however, been used for a genus of Diptera, the description of which appeared in September, 1910. A new name, *Neothomasia*, therefore, is necessary for Wilson's genus.

Characters.—Cornicles present; antennae of six segments armed with subcircular sensoria and prominent hairs. Fore wings with the media twice branched, hind wings with both media and cubitus present. Cauda and anal plate both rounded.

Forms living in colonies upon the leaves or bark of trees; no dimorphic forms produced; sexual forms not markedly different from the viviparous ones. Oviparous females laying several eggs.

Type (monotypical), *Chaitophorus populicola* Thos.

Genus SIPHA Pass.

1860. *Sipha* Passerini, Gli Afidi, p. 29.

This genus and *Atheroides* are distinct from the other genera in the subtribe by possessing five-segmented antennae instead of six-segmented ones. The genus has not been much confused excepting by Thomas's placing of *rubifolii*. For a time some workers in this country were led to conceive of the genus as indicated by that species which in reality belongs in the Aphidini.

Characters.—Cornicles present, truncate, short, almost mere rings. Antennae of five segments armed with large circular sensoria. Body form flat, entire insect covered with rather long stout hairs. Fore wings with the media twice branched, hind wings with both media and cubitus present. Cauda knobbed, anal plate rounded. Forms living upon the leaves of grasses usually in moist localities, sometimes even submerged, the water appearing to affect them little.

Type (fixed by Passerini, 1860), *Aphis glyceriae* Kalt.

Subtribe PTEROCOMMINA.

The subtribe *Pterocommina* is composed of bark-feeding insects, some of which retain quite primitive characters. It is the writer's opinion, however, that they are, as a group, more specialized than the *Chaitophorina*, but closely related. This is indicated by the development of the cornicles met with in the species. Like the

Drepanosiphina, this development varies to a great extent in the different species.

Only two genera occur in the tribe. They may be separated as follows:

KEY TO THE GENERA OF THE PTEROCOMMINA.

Cornicles cylindrical	<i>Pterocomma</i> .
Cornicles somewhat swollen	<i>Melanoxantherium</i> .

Genus PTEROCOMMA Buckton.

Plate IV, PP.

1857. *Cladobius* Koch, Die Pflanzenläuse Aphiden, p. 251.
 1860. *Aphioides* Passerini, Gli Afidi, p. 28.
 1879. *Pterocomma* Buckton, Monog. Br. Aphides, v. 2, p. 142.
 1905. *Aristaphis* Kirkaldy, Can. Ent., v. 37, p. 416.

In 1857 Koch erected the genus *Cladobius* with *populeus* Kalt. as type. This name, however, had been used previously. So Passerini in 1860 employed the name *Aphioides*. This name had also been used. Kirkaldy, therefore, gave the new name *Aristaphis* in 1905. In 1879, however, Buckton described the genus *Pterocomma* with a very similar species as type.

Characters.—Cornicles present, rather short and cylindrical. Antennæ of six segments armed with prominent hairs and subcircular sensoria. Fore wings with the media twice branched; hind wings with both media and cubitus present. Cauda and anal plate rounded.

Type (monotypical), *Pterocomma pilosa* Buckt.

Genus MELANOXANTHERIUM Schouteden.

Plate IV, NN, OO.

1879. *Melanoxanthus* Buckton, Monog. Br. Aphides, v. 2, p. 21.
 1901. *Melanoxantherium* Schouteden, Ann. Ent. Soc. Belg., v. 45, p. 113.

In 1879 Buckton described the genus *Melanoxanthus* with *salicis* L. as type, but, as this name was preoccupied, Schouteden suggested the name *Melanoxantherium*.

Characters.—Cornicles present, variable in size, but usually more or less swollen. Antennæ of six segments armed thickly with hairs and possessing oval or subcircular sensoria. Fore wings with the media twice branched, hind wings with both media and cubitus present. Cauda and anal plate rounded.

Forms living in colonies usually on the bark of trees, males usually winged. Oviparous females laying several eggs.

Type (monotypical), *Aphis salicis* L.¹

Subtribe FULLAWAYINA.

The subtribe Fullawayina is related somewhat closely to the Chaitophorina from which it is a specialization, as is evidenced by the reduction and total lack of the cornicles. It is very suggestive of Monaphis, but evidently arose from quite a different line of development, following Chaitophorus rather than the Callipterus group. Only one genus is represented.

¹ The writer is forced to change his view that *Pterocomma pilosa* is closely related to *populifoliae* Fitch. This was based on Pergande's published statement of his examination of the type. Later notes on the type indicated that it resembles *populca*.

Genus *FULLAWAYA* Essig.

1912. *Fullawaya* Essig, Pomona Coll. Journ. Ent., v. 4, p. 716.

The genus *Fullawaya* seems to bear somewhat the same relation to *Chaitophorus* that *Monaphis* does to *Myzocallis*. Were it not for the hairy condition of the antennæ and the character of the cauda and anal plate, *Fullawaya* might be placed as a synonym of *Monaphis*, but it is evidently unrelated.

Characters.—Cornicles absent; antennæ of six segments, armed with rather long bristle-like hairs, sensoria small and circular, cauda rounded and armed with long curved hairs. Fore wings with the media twice branched, hind wings with both media and cubitus present.

Forms living upon the roots of plants.

Type (monotypical), *Fullawaya saliciradicis* Essig.

Tribe GREENIDEINI.

The tribe Greenideini was first separated by Wilson under the name *Trichosiphina*. The insects falling here show a most remarkable development of the cornicles. These are sometimes as long as the entire body in the alate forms. In the apterous individuals they are usually swollen. In both they are very thickly covered with long hairs, a condition not met with in any of the other Aphidinae with long cornicles. It is true that some species of *Macrosiphum* and occasionally species of the other genera show here and there minute hairs on the cornicles, but they do not approach in any way members of this tribe in cornicle armature. The development of the cauda in this group is also remarkable.

Characters.—Cornicles present and remarkably developed into cylindrical or slightly swollen tubes often as long as the body and thickly covered with long hairs. Antennæ of five or six segments armed with oval or subcircular sensoria. Males winged. Forms living free upon the foliage.

KEY TO GENERA OF GREENIDEINI.

1. Antennæ of five segments.....*Eutrichosiphum*.
 Antennæ of six segments..... 2.
2. Fore wings with the media twice branched, hind wings with both
 media and cubitus present.....*Greenidea*.
 Fore wings with media once branched, hind wings with neither media
 nor cubitus present.....*Greenideoida*.

Genus *GREENIDEA* Schouteden.

Plate V, F-K.

1905. *Greenidea* Schouteden, Spol. Zeylan, v. 2, p. 181.

1906. *Trichosiphum* Pergande, Ent. News, v. 17, p. 206.

In 1905, Schouteden erected a genus for the *Siphonophora artocarpi* of Westwood and redescribed the species, giving details lacking in Westwood's paper. Pergande erected his genus *Trichosiphum*, making his *anona* the type. The characters Pergande used to separate his genus were in reality those of *Greenidea*.

Characters.—Cornicles extremely long and hairy; antennae of six segments armed with oval or subcircular sensoria and distinct hairs. Fore wings with media twice branched; hind wings with both media and cubitus present. Sexes winged.

Type (monotypical), *Siphonophora artocarp*i Westw.

Genus GREENIDEOIDA Van der Goot.

Plate V, L-P.

1900. *Greenidea* Wilson, not Schouteden, Ann. Ent. Soc. Amer., v. 3, p. 317.

1916. *Greenideoida* Van der Goot, Zur Kenntniss der Blattläuse Java's, p. 140.

In discussing the genera of the Trichosiphini in 1910, Wilson based his descriptions and key on specimens in the collection of the Bureau of Entomology. Material in that collection determined as *artocarp*i by Pergande proves not to be that species for it does not agree with the descriptions given either by Westwood or Schouteden. Wilson, therefore, used the two generic terms *Trichosiphum* and *Greenidea*. In reality the species listed as *artocarp*i was undescribed at that time and the species of *Trichosiphum* presented all of the characters of *Greenidea*. Since that time Van der Goot has erected the genus *Greenideoida* for such species as that understood by Wilson to be *artocarp*i.

Characters.—Cornicles present, very long, subcylindrical, and armed with long hairs. Antennae of six segments armed with oval or subcircular sensoria. Fore wings with the media once branched; hind wings reduced in size and lacking both the media and cubitus. Cauda and anal plate rounded.

Type (fixed by Van der Goot, 1916), *Greenideoida elongata* V. d. Goot.

Genus EUTRICHOSIPHUM Essig & Kuwana.

Plate V, A-E.

1918. *Eutrichosiphum* Essig & Kuwana, Proc. Cal. Acad. Sci., v. 8, no. 3, p. 97.

The genus *Eutrichosiphum* Essig and Kuwana was erected for the species *pasaniae* Okj.

Characters.—Similar in general characters to *Greenidea*. Antennae of five segments, armed with long hairs and somewhat oval sensoria. Cornicles very long, subcylindrical and covered with hairs. Fore wings with the media twice branched, hind wings with both media and cubitus present. Cauda and anal plate rounded.

Type (monotypical), *Trichosiphum pasaniae* Okj.

Tribe SETAPHIDINI.

The correct position of the tribe Setaphidini is somewhat difficult to ascertain. In some ways it closely resembles the Aphidini, and in others suggests the Lachnini.

It has Aphis-like antennae with, however, a reduced number of segments. The venation of the wings is also reduced. On the other hand it possesses cornicles situated on low flat cones somewhat like those of the Anoecina or Lachnina. But these cones are devoid of hairs.

It would appear that this tribe separated from the aphid line after the cornicles had lost their armature and before their development as indicated in the Aphidina and Macrosiphina began. These organs then remained somewhat primitive whereas reduction took place in the antennæ and wings. One genus only is represented.

Genus *SETAPHIS* Van der Goot.

Plate V, Q-X.

1916. *Setaphis* Van der Goot, Zur Kenntniss der Blattläuse Java's, p. 153.

Characters.—Cornicles present as rings, situated on low broad cones. Antennæ of five segments armed with small circular sensoria. Fore wings with the media once branched, hind wings reduced. Cauda and anal plate rounded. Body with two prominent caudal fingerlike projections.

Type (fixed by Van der Goot, 1916), *Setaphis luteus* V. d. Goot.

Tribe APHIDINI.

The tribe Aphidini is by far the largest tribe of the living Aphididae. Many of the most common species in the family as well as many of the most injurious ones belong here, and it is these forms which correspond to the popular conception of the family.

Besides being abundant they are varied, and a large number of genera is therefore found in this tribe. Specialization has taken place in a number of directions, but particularly in the development of cornicles, cauda, etc. The wings have become somewhat reduced in certain genera, but as a rule little reduction in these organs has occurred, the venation in most cases being as complete as in even the most primitive forms of the family. The antennæ have developed an elongate filamentous process to the distal segment, which in the Lachnini is represented by a very short thumblike projection. Wax secretion is found scarcely at all apart from that produced and secreted by the cornicles. The head shows certain peculiar developments in some of the tribes in that the antennæ are situated on prominent tubercles variously shaped and armed.

As a rule the body is more or less naked, being covered only by a few scattered hairs. In the peculiar specialized Cervaphidina, however, large toothed processes extend outward from the body surface.

Migration between a primary host and one or more secondary hosts often occurs. Apterous and alate viviparous forms, therefore, are common, but no definite relation exists between them. The forms feed mostly upon the leaves of trees and herbs but they may also be found feeding upon the twigs and roots. They are not infrequently attended by ants. The oviparous females are nearly always apterous, but the males, on the other hand, usually are winged. Apterous males, however, are common and intermediate forms between alate males and apterous males sometimes occur. Inter-

mediates between apterous and alate viviparous forms are of quite common occurrence and indicate possible origin of the apterous forms. It is no doubt true, however, that in members of this tribe the equilibrium is disturbed more easily than in some of the others, and that external influences have a more sudden and noticeable effect.

We have divided the tribe into four subtribes which may be separated as follows:

KEY TO THE SUBTRIBES OF THE APHIDINI.

1. Body covered with long projections..... CERVAPHIDINA.
Body naked with the exception of a few hairs..... 2.
2. Head without prominent antennal tubercles..... APHIDINA.
Head with prominent antennal tubercles..... 3.
3. Wings with the radial sector normal..... MACROSIPHINA.
Wings with the radial sector more or less united with the upper branch of
the media or hind wings reduced PENTALONINA.

Subtribe APHIDINA.

The insects in the Aphidina show a great variation in regard to the cornicles and cauda. Some have very markedly developed cornicles, others have extremely small ones, while one genus lacks them altogether. The cauda varies from very large in genera like *Hyalopterus* to scarcely any visible cauda in some of the other genera. Certain of the genera appear more similar than others, for example, *Hyalopterus*, *Pergandeidia*, and *Brachycolus* all have small cornicles and somewhat large caudæ. Certain other genera, while appearing quite different in some ways, are evidently related. *Cavariella*, *Hyadaphis*, *Aspidaphis*, and *Vesiculaphis* all have characters which are very suggestive, although there are differences between them. So also there is a group suggesting *Aphis*. The various genera may be separated as follows:

KEY TO THE GENERA OF THE APHIDINA.

1. Cornicles absent..... Asiphonaphis.
Cornicles present..... 2.
2. Cornicles swollen, not subcylindrical or tapering..... 3.
Cornicles subcylindrical or tapering but sometimes extremely short and
ringlike 12.
3. Fore wings with the media once branched; apterous form with very much
swollen cornicles..... Vesiculaphis.
Fore wings with the media twice branched 4.
4. Hind wings with the cubitus lacking..... Carolinaia.
Hind wings with both media and cubitus present..... 5.
5. Abdomen with a dorsal projection or tubercle above cauda..... 6.
Abdomen without this structure..... 7.

6. Tubercle very large, entirely covering posterior part of body; cornicles small, opening at the side..... *Aspidaphis*.
 Tubercle of moderate size, as large as cauda in the apterous form; cornicles normal, opening at the end..... *Cavariella*.
7. Cornicles long, very abruptly and distinctly swollen..... *Liosomaphis*.
 Cornicles of varying lengths, gradually swollen..... 8.
8. Cauda short and abruptly conical; cornicles about the same length as cauda and swollen in the middle..... *Brevicoryne*.
 Cauda not strikingly short or abruptly conical..... 9.
9. Cornicles as short as the width of cauda at base or shorter..... 10.
 Cornicles as long as or longer than the cauda..... 11.
10. Cornicles minute, tubercle-like..... *Brachycolus*.
 Cornicles considerably longer than their diameter; cauda, particularly in the apterous form, large and long..... *Hyalopterus*.
11. Cauda in the apterous form long and broad, as long as the cornicles.. *Hyadaphis*.
 Cauda shorter than the cornicles, not correspondingly long and broad..... *Rhopalosiphum*.
12. Tarsi atrophied..... 13.
 Tarsi normal..... 14.
13. Antennæ of six segments; cornicles rather short..... *Atarsos*.
 Antennæ of five segments; cornicles very long and slender..... *Mastopoda*.
14. Cauda apparently absent, or a mere rounded platelike structure..... 21.
 Cauda normal in appearance but often very short..... 15.
15. Fore wings with media once branched..... 22.
 Fore wings with media twice branched..... 16.
16. Antennæ of five segments..... 24.
 Antennæ of six segments..... 17.
17. Cornicles small, as short as width of cauda at base, which is without constriction..... 18.
 Cornicles usually as long as or longer than cauda, *Aphis*-like..... 19.
18. Cauda very long and large in the apterous form..... *Pergandeidia*.
 Cauda extremely short and subconical..... *Microsiphum*.
19. Cauda short and abruptly conical..... *Anuraphis*.
 Cauda elongate and constricted near base..... 20.
20. Hind wings with media and cubitus present..... *Aphis*.
 Hind wings with only one oblique vein..... *Hysteroneura*.
21. Cornicles minute, not as long as wide..... *Cryptosiphum*.
 Cornicles moderate in length..... *Acaudus*.
22. Antennæ of six segments..... *Toxoptera*.
 Antennæ of five segments..... 23.
23. Apterous form with a prominent median projection on the vertex and with four-segmented antennæ; cornicles minute..... *Sanbornia*.
 Apterous form normal..... *Yamataphis*.
24. Cornicles elongate, *Aphis*-like..... *Cerosipha*.
 Cornicles extremely short, body of apterous form, much arched. *Siphonatrophia*.

Genus *ACAUDUS* V. d. Goot.

Plate VI, A, B.

1913. *Acaudus* Van der Goot, Tijd. voor Ent., v. 56, p. 97.

1917. *Macchiatiella* Del Guercio, Redia, v. 12, p. 210.

1917. *Hannabura* Matsumura, Journ. Coll. Agr. Tohoku Univ., v. 7, pt. 6, p. 377.

Van der Goot erected his genus *Acaudus* with *lychnidis* L. as type. This species is quite similar to an *Aphis* without a cauda or with a very short, somewhat rounded cauda. The cornicles are not long.

Del Guercio's genus had his *trifolii* placed as type. The cornicles of this species appear to be a little longer than those of the type of Van der Goot's genus, but in other respects the insects seem to be quite similar. We feel that they belong to the same genus. We are keeping this genus distinct from *Cryptosiphum*, not only because of the minute cornicles in that genus but also on account of the peculiar head structure which is there seen. It is not typically *Aphis*-like.

Characters.—Head without prominent antennal tubercles. Antennae of six segments. Fore wings with the media twice branched; hind wings with both media and cubitus present. Cornicles cylindrical, of moderate length; cauda reduced to a broad, short, rounded structure.

Type (fixed by Van der Goot, 1913), *Aphis lychnidis* L.

Genus **ANURAPHIS** Del Guercio.

Plate VI, C-F.

- 1907. *Anuraphis* Del Guercio, Redia, v. 4, p. 190.
- 1913. *Brachycaudus* Van der Goot, Tijd. voor Ent., v. 56, p. 97.
- 1913. *Dentatus* Van der Goot, Tijd. voor Ent., v. 56, p. 98.
- 1913. *Semiaphis* Van der Goot, Tijd. voor Ent., v. 56, p. 105.
- 1917. *Yezabura* Matsumura, Journ. Coll. Agr. Tohoku Univ., v. 7, pt. 6, p. 392.
- 1918. *Sappaphis* Matsumura, Trans. Sapporo Nat. Hist. Soc., v. 7, pt. 1, p. 18.

In 1907 Del Guercio erected the genus *Anuraphis* in which were included *pyri* Koch, *lappae* Koch, *iridis* Del Guercio, *ranunculi* Kalt., *myosotidis* Koch, *centaureae* Koch, *prunicola* Kalt., *tragopogonis* Kalt., *iani* Feer, *farfarae* Koch, and *persicae* Boyer.

These species, with the exception of *lappae* and *tragopogonis* which seem to belong to *Aphis*, have a broadly and somewhat abruptly conical cauda quite unlike that of the genus *Aphis*. In 1913, Van der Goot erected his genus *Brachycaudus* with one of these species, *myosotidis*, as type without referring any of the species to *Anuraphis* at all. It is evident that *Brachycaudus* is a synonym of *Anuraphis*. At the same time he erected the genus *Semiaphis* with *carotae* Koch as type. A study of this species, as seen in Plate VI, makes it evident that this is a species of the same general type. *Semiaphis* thus becomes a synonym of *Anuraphis*. Based on the minute tubercles, particularly on the head and caudal portion of the abdomen, Van der Goot also erected the genus *Dentatus* with *sorbi* Kalt. as type. Apart from these tubercles *sorbi* is in the character of the cauda, etc., a typical *Anuraphis*. In our American rosy aphid, a species very similar to *sorbi*, these tubercles are absent in many individuals, and in the fall migrants the caudal ones are nearly always absent. If this character were retained, therefore, the species would belong in one genus as far as the spring migrant is concerned, and in another genus when the fall migrant is considered. *Dentatus*, therefore, becomes also a synonym of *Anuraphis*.

Characters.—Head without prominent antennal tubercles. Antennae of six segments and armed with subcircular sensoria. Fore wings with the media twice branched, hind wings with both media and cubitus present. Cornicles cylindrical, often short, though sometimes moderately long; cauda short, broad, and abruptly conical, never elongate and constricted as in *Aphis*. Males usually winged. Oviparous forms apterous.

Type (fixed by Del Guercio, 1907), *Aphis pyri* Koch.

Genus APHIS L.

Plate VI, G-I.

- 1758. *Aphis* Linnaeus, Systema Naturae, 10th ed., p. 451.
- 1817. *Loxerates* Rafinesque, Am. Mo. Mag. & Crit. Review, v. 1, p. 361.
- 1907. *Uraphis* Del Guercio, Redia, v. 4, p. 192.
- 1907. *Microsiphon* Del Guercio, Redia, v. 4, p. 192.
- 1913. *Myzaphis* Van der Goot, Tijd. voor Ent., v. 56, p. 96.
- 1913. *Stenaphis* Del Guercio, Redia, v. 9, p. 185.
- 1916. *Longiunguis* Van der Goot, Zur Kenntniss der Blattläuse Java's, p. 112.
- 1916. *Melanaphis* Van der Goot, Zur Kenntniss der Blattläuse Java's, p. 61.
- 1917. *Abura* Matsumura, Jour. Coll. Agr. Tohoku Univ., v. 7, pt. 6, p. 407.
- 1917. *Arimakia* Matsumura, Jour. Coll. Agr. Tohoku Univ., v. 7, pt. 6, p. 405.

A number of species were included in the original genus by Linnaeus. Of these Lamarek set *Aphis ulmi* L. as type in 1801, and in 1802 Latreille set *Aphis sambuci* L. as type. *Aphis ulmi* L. is, according to Passerini, *Eriosoma lanuginosa* Hartig and the species now placed in *Tetraneura*. *Sambuci* is retained here as type and a request will be submitted that this species be fixed definitely by the International Commission. It would greatly disarrange the economic literature to change the meaning of this common name.

In 1907 Del Guercio erected two genera, *Uraphis* and *Microsiphon* based on the relative length of the cornicles and cauda. When considering certain individual species this would appear as a very fair character for use. But when large series of species are studied it will be found that in the species having the cauda of the typical *Aphis* shape there are all gradations of cornicles from the very short to the very long. This will be seen also in the forms having the abruptly conical cauda. Some species have very short cornicles and some quite long ones. Moreover, in the same species the cornicles in the different forms will bear a different relation to the length of the cauda. Species, therefore, having cornicles and cauda of essentially the same character should not be used as types of different genera depending on the length of the cornicles. If this were the case, certain species which are close to the border line of separation would on some individuals fall in one genus and on other individuals fall in a different genus. Under this rule, *sacchari* Zehnt. would, it is believed, belong to the genus *Aphis*, and *Longiunguis*, therefore, be a synonym of *Aphis*. Likewise the genus *Melanaphis* would be a synonym of *Aphis*. This genus was erected with *bambusae* Kirk. as type. The cornicles are short but the cauda is *aphis*-like. Where the generic characters are considered, the genus appears a synonym.

The genus *Myzoaphis* was erected by Van der Goot with *Aphis rosarum* Kalt. and *Aphis abietina* Walker. These two species show practically no antennal tubercles and are very little different from a typical *Aphis*, excepting in the clothing of the antennæ and body. The cauda as figured by Van der Goot is quite conical, but the writer's specimens are somewhat different from this and specimens of *abietinus* do not show a cauda exactly like his figure. In fact, they appear more like an *Aphis*. This genus, therefore, should not be separated or it will necessitate the separation of very many other forms under new names.

Characters.—Head without prominent antennal tubercles. Antennæ of six segments and armed with subcircular sensoria. Fore wings with the media twice branched; hind wings with both media and cubitus present. Cornicles cylindrical or slightly tapering. Cauda usually not as long as the cornicles, subconical, rather elongate, constricted about the middle. Anal plate rounded. Males usually winged, oviparous females apterous.

Type (by suspension of rules), *Aphis sambuci* L.

Genus ASPIDAPHIS Gillette.

Plate VI, L-O.

1917. *Aspidaphis* Gillette, Can. Ent., v. 49, p. 196.

The genus *Aspidaphis* appears to be related both to *Cavariella* and to *Vesiculaphis*. It has the short, blocky form of *Vesiculaphis* and also the peculiar integument. On the other hand, certain species with a similar integument are met with in *Cavariella*. The development of the dorsal abdominal tubercle is here very pronounced and the cornicles have taken on a peculiar shape.

Characters.—Head without prominent antennal tubercles; antennæ short, of five segments, armed with subcircular sensoria. Wing venation normal. Cornicles very small, somewhat swollen near the distal extremity and with the opening in the side of the cornicle, not at the tip. Abdomen with a dorsal caudal tubercle developed into a large conical process extending beyond and fully covering the cauda in the apterous form. Body elongate.

Type (monotypical), *Aspidaphis polygonii* Gill.

Genus ASIPHONAPHIS Wilson & Davis.

1919. *Asiphonaphis* Wilson & Davis, Ent. News, v. 30, p. 39.

Characters.—Head without prominent antennal tubercles. Antennæ of six segments armed with subcircular sensoria. Fore wings with the media twice branched; hind wings with both media and cubitus present. Cornicles absent entirely. Abdomen with large lateral tubercles. Cauda somewhat conical or *Aphis*-like. Anal plate rounded.

Type (monotypical), *Asiphonaphis pruni* Wilson & Davis.

Genus ATARSOS Gillette.

Plate VI, P-S.

1911. *Atarsos* Gillette, Ent. News, v. 22, p. 440.

Characters.—Head without prominent antennal tubercles. Antennæ of six segments armed with subcircular, somewhat tuberculate sensoria; fore wings with the media twice branched, hind wings with both media and cubitus present. Cornicles rather

short, subcylindrical; cauda somewhat conical, not quite as long as the cornicles; anal plate rounded. Tarsi atrophied in all the forms.

Type (monotypical), *Atarsos grindeliae* Gill.

Genus **BRACHYCOLUS** Buckton.

Plate VI, T, U.

1879. *Brachycolus* Buckton, Mon. British Aphides, v. 2, p. 146.

1913. *Brachysiphum* Van der Goot, Tijds. voor Ent., v. 56, p. 105.

The genus *Brachycolus* was erected with *stellariae* Hardy as type and is easily recognized from the structure of the cornicles. Van der Goot's genus is in all essential respects the same, the type of that genus being *thalietri* Koch.

Characters.—Head without prominent antennal tubercles. Antennae of six segments and armed with subcircular sensoria. Wing venation normal. Cornicles very small, especially in the apterous form. Cauda medium in size and conical. Body elongate; legs and antennae usually short.

Type (monotypical), *Aphis stellariae* Hardy.

Genus **BREVICORYNE** V. d. Goot.

Plate VI, J, K.

1915. *Brevicoryne* Van der Goot, Beiträge z. Kennt. d. Holl. Blattläuse, p. 245.

1916. *Oedisiphum* Van der Goot, Zur Kenntniss der Blattläuse Java's, p. 122.

1918. *Brevicoryne* Das, Mem. Ind. Mus., v. 6, p. 179.

The genus *Brevicoryne* was erected with *Aphis brassicae* L. as type, a species in which the cornicles are very short and somewhat swollen in the middle, and the cauda conical. In the species *Oedisiphum compositarum* V. d. Goot quite similar characters are found. The cornicles appear to be somewhat more slender but in the main the species appear alike. *Oedisiphum*, therefore, becomes a synonym.

Characters.—Head without prominent antennal tubercles; antennae of six segments and armed with subcircular sensoria. Wing venation normal. Cornicles short, not much longer than the cauda and swollen in the middle. Cauda short and broadly conical.

Forms not especially elongate.

Type (monotypical), *Aphis brassicae* L.

Genus **CAROLINAIA** Wilson.

Plate VI, V, W.

1911. *Carolinaia* Wilson, Can. Ent., v. 43, p. 61.

The genus *Carolinaia* Wilson is related very closely to *Rhopalosiphum*. In fact some of the species placed here are distinguished from members of that genus only by the fact that the cubitus is lacking in the hind wing. It is true that the type species was described as having five-segmented antennae in the apterous form. But other species, like this in all other respects, have normal six-segmented antennae. Certain species of *Rhopalosiphum* will show strains in which nearly all of the individuals will have five-segmented antennae and yet the normal antenna for such species is a six-segmented one. In this closely related genus, therefore, it is not surprising if a similar condition is met with.

Characters.—Head without prominent antennal tubercles. Antennæ of five or six segments armed with subcircular sensoria. Venation of the fore wings normal; hind wings with the cubitus absent; cornicles elongate, slightly swollen near the distal extremity, but without a prominent neck near the proximal end. Cauda rather broadly conical.

Type (monotypic), *Carolinaia caricis* Wlsm.

Genus CAVARIELLA Del Guercio.

Plate VI, X-Z.

1911. *Cavariella* Del Guercio, Redia, v. 7, p. 323.

1914. *Corynosiphon* Mordwilko, Faune de la Russie Insecta, Aphidodea, p. 73.

1917. *Nipposiphum* Matsumura, Journ. Coll. Agr. Tohoku Univ., v. 7, pt. 6, p. 410.

Two new genera were erected in recent years: One by Del Guercio, Cavariella, with *pastinacae* L. as type; the other by Mordwilko, called Corynosiphon, but with no species definitely given. In a footnote, however, Mordwilko refers *capreae* Fab. to his Corynosiphon. Both of these genera, therefore, were used for insects of the same general type. This may be said too of Nipposiphum.

Characters.—Head without distinct antennal tubercles; antennæ of six segments, armed with prominent sensoria. Wing venation normal. Cornicles somewhat swollen near the distal end; cauda rather elongate, somewhat conical; abdomen with a tubercle or horn above the cauda, this tubercle or horn most prominent in the apterous form. Males winged; oviparous females usually apterous.

Type, *Aphis pastinacae* L.¹

Genus CEROSIPHA Del Guercio.

1900. *Cerosipha* Del Guercio, Nuove Rel. Staz. Firenze, ser. 1, no. 2, p. 116.

1918. *Metaphis* Matsumura, Trans. Sapporo Nat. Hist. Soc., v. 7, pt. 1, p. 1.

The genus Cerosipha Del Guercio was erected for a species, *passeriniana* Del Guercio, somewhat similar to Aphis but with five segments to the antennæ. The writer has been unable to study the type species and has based his remarks on *rubifolii* Thomas, an American species.

Characters.—Head without prominent antennal tubercles; antennæ of five segments, Aphis-like, armed with subcircular sensoria. Fore wings with the media twice branched, hind wings with both media and cubitus present. Cornicles cylindrical or somewhat tapering, cauda Aphis-like, somewhat tapering.

Type (monotypic), *Cerosipha passeriniana* Del G.

Genus CRYPTOSIPHUM Buckton.

Plate VI, PP, QQ.

1879. *Cryptosiphum* Buckton, Mon. Br. Aphides, v. 2, p. 144.

The genus Cryptosiphum Buckton can be distinguished from others having very short cornicles by the cauda which is here short and rounded, while in most other cases it is very long.

Characters.—Head without distinct antennal tubercles. Antennæ of six segments, rather short, and with subcircular sensoria. Fore wings with the media either once or twice branched. Hind wings with both media and cubitus present. Cornicles sub-

¹The writer has a record to the effect that in a published paper Del Guercio used *pastinacae* as type of Cavariella, but he has been unable to locate the publication and can not reach Doctor Del Guercio through the mails.

cylindrical but extremely short, not as long as wide. Cauda very short and rounded, not Aphis-like; anal plate rounded.

Type (monotypical), *Cryptosiphum artemisiae* Buckt.

Genus **HYSTERONEURA** Davis.

1919. *Heteroneura* Davis, Can. Ent., v. 51, p. 228.

1919. *Hysteroneura* Davis, Can. Ent., v. 51, p. 263.

Characters.—Head without prominent antennal tubercles. Antennæ of six segments armed with subcircular sensoria. Fore wings with the media twice branched. Hind wings with the cubitus absent. Cornicles somewhat tapering or subcylindric, cauda Aphis-like; anal plate rounded.

Type (monotypical), *Aphis setariae* Thos.

Genus **HYADAPHIS** Kirk.

Plate VI, AA, BB.

1904. *Hyadaphis* Kirkaldy, The Entomologist, v. 37, p. 279.

1863. *Siphocoryne* Passerini, Aphididae Italicae, p. 8 (not *Siphocoryne*, 1860).

As indicated under the discussion of *Siphocoryne*, Passerini set *xylostei* as type of his genus in 1863. *Nymphæae* had, however, been set in 1860, so Kirkaldy gave *Hyadaphis* to Passerini's 1863 conception, of which genus *xylostei* becomes the type. *Xylostei* has no caudal horn and is quite similar in general appearance to a *Rhopalosiphum*. We may separate the two genera, however, on the cauda, which in *xylostei*, particularly in the apterous form, is very large, fully as long as the cornicles, and broad, quite unlike that of *nymphæae*. Several other species which have generally been considered in the same genus with *xylostei* possess a distinct caudal projection on the abdomen. One of these has been made the type of *Cavariella* so that such species will be removed from our conception of *Hyadaphis*.

Characters.—Head without prominent antennal tubercles; antennæ of six segments which are rather abundantly armed with tuberculate sensoria. Wing venation normal. Cornicles somewhat swollen but not prominently so. Cauda, particularly in the apterous form, large, as long as the cornicles, and broad. Males usually winged; oviparous females apterous; summer forms usually feeding on the Umbelliferae.

Type (fixed by Kirkaldy, 1904), *Aphis xylostei* Schrk.

Genus **HYALOPTERUS** Koch.

Plate VI, RR-WW.

1854. *Hyalopterus* Koch, Die Pflanz. Aphiden, p. 16.

1917. *Hayhurstia* Del Guercio, Redia, v. 12, p. 208.

Aphis pruni Fab. was set as the type of this genus in 1860 by Passerini. In 1917 Del Guercio erected the genus *Hayhurstia*. There is little difference between the two as will be seen by examining the drawings given herewith. The cauda in *Hayhurstia* is slightly narrower than that in *Hyalopterus*. It is the writer's opinion that the two represent only one genus.

Two other genera may be mentioned here. They are *Brachycolus* Buckt. and *Pergandeidia* Schout. Specimens of the type species of *Brachycolus* show that this genus is quite similar to *Hyalopterus*, but it differs in the cornicles. In *Brachycolus* the cornicles are very small, almost mere rounded swellings in the apterous form, whereas

in *Hyalopterus* the cornicles are in the apterous form of fair size and not distinctly swollen.

Specimens of the type of *Pergandeidia* received from Schouteden show that this genus is very close to *Hyalopterus* and is probably almost too close for a very distinct genus. The diagnosis given by Wilson (1910) for this genus does not agree with the type species as determined by the author of the genus.

In the specimens examined by the writer the cauda, as will be seen in the drawings, is very much longer than the cornicles, bearing about the same ratio as seen in *Hyalopterus*.

Characters.—Head without distinct antennal tubercles, antennæ of six segments armed with subcircular sensoria. Wing venation normal. Cornicles very short, not much longer than the cauda is wide at its base, swollen beyond the middle, particularly in the alate form. Cauda long and broad, considerably longer than the cornicles. Form of the insects elongate, often more or less flat.

Type (fixed by Passerini, 1860), *Aphis pruni* Fab. (= *A. arundinis* Fab.).

Genus LIOSOMAPHIS Walker.

Plate VI, NN, OO.

1868. *Liosomaphis* Walker, The Zoologist, p. 1119.

The genus *Liosomaphis* Walker is related somewhat closely to *Rhopalosiphum*. The two genera, however, can be separated on the structure of the cornicles.

In *Liosomaphis* the cornicles have a very distinct neck near the proximal extremity, due to a constriction behind the prominent swelling. This is strikingly evident in the apterous form, as well as in the alate one. In *Rhopalosiphum*, on the other hand, there is no abrupt swelling, but only a gradual one which is not at all prominent, as in *Liosomaphis*.

Characters.—Head without prominent antennal tubercles. Antennæ of six segments armed with subcircular sensoria. Wing venation normal. Cornicles elongate, distinctly swollen in the middle, and with a constricted neck near the base. Structure in both the apterous and alate forms similar. Cauda not as long as the cornicles, somewhat narrowly conical. Males usually winged; oviparous females usually apterous.

Type (monotypical), *Aphis berberidis* Kalt.

Genus MASTOPODA Oestlund.

1886. *Mastopoda* Oestlund, Minn. Geol. Surv. Rept. 14, p. 52.

The genus *Mastopoda* Oestlund, like Gillette's *Atarsos*, is peculiar in that the tarsi are atrophied.

Characters.—Head without distinct antennal tubercles. Antennæ of five segments. Fore wings with the media twice branched, hind wings with both media and cubitus present. Cornicles somewhat long and cylindrical. Cauda short, conical, Aphis-like. Legs with the tarsi absent and provided instead with a membranous disk which enables the insect to walk inverted on smooth surfaces.

Type (monotypical), *Mastopoda pteridis* Oestlund.

Genus *MICROSIPHUM* Cholodkovsky.

1908. *Microsiphum* Cholodkovsky, Zool. Anz., v. 32, p. 687.

Characters.—Head without prominent antennal tubercles, although with apparent ones. Antennæ of six segments, rather long and slender. Fore wings with the media twice branched; hind wings with both media and cubitus present. Cornicles very short, not much longer than wide and often scarcely visible in the alate form. Cauda extremely short and subconical or slightly rounded; anal plate rounded.

Type (monotypical), *Microsiphum ptarmicæ* Chol.

Genus *PERGANDEIDIA* Schouteden.

Plate VI, KK-MM.

1903. *Pergandeidia* Schouteden, Zool. Anz., v. 26, p. 685.

1913. *Longicaudus* Van der Goot, Tijd. voor Ent., v. 56, p. 146.

1915. *Rhizobertesia* Del Guercio, Redia, v. 10, p. 246.

1918. *Yezosiphum* Matsumura, Trans. Sapporo Nat. Hist. Soc., v. 7, pt. 1, p. 7.

1918. *Brachyunguis* Das, Mem. Ind. Mus., v. 6, p. 227.

The genus *Pergandeidia* was erected by Schouteden with his *ononidis* as type. The characterization of the genus in this paper is based on specimens of the species received from Schouteden, and though it does not agree with the characterization of the genus as sometimes given, it seems necessary to follow the type species in forming a conception of the genus. In 1913 Van der Goot erected the genus *Longicaudus* and placed *trirhodus* Walker as type. In studying this species differences sufficient for good generic distinction have not been found, and, therefore, the conclusion may be drawn that *Longicaudus* is a synonym of *Pergandeidia*. Del Guercio's genus is placed here also, although a study of the type species, which is not available, possibly may show the cauda to be somewhat different.

Characters.—Head with no prominent antennal tubercles; antennæ of six segments. Fore wings with media twice branched, hind wings with both media and cubitus present. Cornicles very short, almost as wide as long. Cauda very long and broad.

Type (monotypical), *Pergandeidia ononidis* Schout.

Genus *RHOPALOSIPHUM* Koch.

Plate VI, FF-JJ.

1854. *Rhopalosiphum* Koch, Die Pflanz. Aphiden, p. 23.

1860. *Siphocoryne* Passerini, Gli Afidi, p. 28.

1882. *Rhopalosiphon* Scudder, Nomenclator Zoologicus.

1910. *Coloradoa* Wilson, Ann. Ent. Soc. Am., v. 3, p. 323.

1915. *Siphonaphis* Van der Goot, Beiträge zur Kennt. d. Holl. Blattläuse, p. 238.

1918. *Stephensonia* Das, Mem. Ind. Mus., v. 6, p. 175.

1856. (Type fixation) Gerstaecker, Bericht for 1854, p. 162.

There has been much confusion in regard to this genus. Koch included a number of diverse species. In 1856 Gerstaecker definitely set *Aphis nymphaeae* L. as type. Overlooking this, Passerini in 1860 set *persicae* Sulz. as type. In 1863, however, he changed this name to *dianthi* Schrank. In 1860 Passerini erected the genus *Siphocoryne* with *A. nymphaeae* L. as type. Having the same type this must, therefore, become a synonym of *Rhopalosiphum*. In 1863 Passerini placed *nymphaeae* in *Rhopalosiphum*, although he set *dianthi*

as type, and he used *Siphocoryne* in a different sense with *xylostei* Schrank as type. Such a procedure is inadmissible, and Kirkaldy therefore renamed this genus *Hyadaphis*.

The genus *Coloradoa* Wilson was erected with *rufomaculata* Wilson as type. Although much smaller, this species is essentially like *nymphææ* in structure, and we therefore consider the genus a synonym of *Rhopalosiphum*.

The genus *Siphonaphis* Van der Goot was erected with *nymphææ* L. as type. Having the same type, therefore, it must become a synonym of *Rhopalosiphum*. *Lahorensis* Das is quite similar.

Characters.—Head without prominent antennal tubercles. Antennæ of six segments with the usual subcircular sensoria present. Wing venation normal. Cornicles moderately long and slender, slightly swollen near their distal extremities. Cauda rather elongate, not as long as the cornicles, and not broad. Abdomen without a caudal horn or projection above the cauda. Males usually winged; oviparous females usually apterous.

Type (fixed by Gerstaecker, 1856), *Aphis nymphææ* L.

Genus **SANBORNIA**, n. gen.

Plate VII, F-L.

The genus *Sanbornia* is erected for a peculiar form living on juniper at College Station, Tex., and forwarded to the Bureau by Charles Sanborn. This species was determined as undescribed by Mr. Pergande who had planned to publish on it. He had given it the name *juniperi*. The type is in the U. S. National Museum (Cat. No. 23064).

Characters.—Head without prominent antennal tubercles. Antennæ of five segments, armed with circular sensoria. Fore wings with the media once branched, hind wings with only the media present, cornicles minute; cauda elongate. Apterous form with four-segmented antennæ and with a prominent mushroom-like projection on the vertex.

Type, *Sanbornia juniperi* Perg.

Sanbornia juniperi Pergande, n. sp.

(Description by Mr. T. Pergande.)

Apterous form.—The head is most remarkable in front, having a large, squarish, bilobed projection about the middle and each side of it; close to the insertion of the antennæ is a prominent, short, and conical protuberance. There is also at the inner side of the first antennal joint a long and slightly conical protuberance. The antennæ are but four-jointed, the spur shorter than the basal section of the joint. Nectaries are not visible (?); the tail is rather long and uniformly elongate conical; the tarsi are very short, the first joint appears to be minute, and in alcoholic specimens seems to be withdrawn into the tibiæ; the last abdominal segment is semicircular.

Genus SIPHONATROPHIA Swain.

Plate VII, A-E.

1918. *Siphonatrophia* Swain, Ent. News, v. 29, p. 363.

Characters.—Head without prominent antennal tubercles. Antennæ of five segments and armed with circular sensoria. Fore wings with the media twice branched; hind wings with both media and cubitus present. Cauda elongate and conical. Cornicles extremely short. Body of apterous form considerably arched.

Type (monotypical), *Cerosipha cupressi* Swain.

Genus YAMATAPHIS Matsumura.

1917. *Yamataphis* Matsumura, Jour. Coll. Agr. Tohoku Univ., v. 7, pt. 6, p. 412.

Characters.—Head without prominent antennal tubercles. Antennæ of five segments armed with small circular sensoria. Fore wings with the media once branched; hind wings with both media and cubitus present. Cornicles subcylindrical. Cauda somewhat conical.

Type (fixed by Matsumura, 1917), *Yamataphis oryzae* Mats.

Genus TOXOPTERA Koch.

Plate VI, DD, EE.

1857. *Toxoptera* Koch, Die Pflanz. Aphiden, p. 253.

1891. *Ceylonia* Buckton, Ind. Mus. Notes, v. 2, p. 35.

Koch's genus was erected for his *aurantiae*, a well-known species on citrus, etc. Buckton erected his genus for a species he described as *theaecola*. Specimens of *aurantiae* from various regions and specimens of *theaecola* from Zehntner substantiate the placing of *theaecola* as a synonym of *aurantiae*. *Ceylonia* will then become a synonym of *Toxoptera*. Even if the two species were held to be distinct, this would necessarily be the case.

Characters.—Head without prominent antennal tubercles. Antennæ of six segments, armed with subcircular sensoria. Fore wings with the media once branched, hind wings with both media and cubitus present. Cornicles moderate in length, subcylindric, tapering. Cauda of moderate length, somewhat constricted near the base.

Type (monotypical), *Toxoptera aurantiae* Koch (*aurantiae* Boyer).

Genus VESICULAPHIS Del Guercio.

Plate VII, M-Q.

1911. *Vesiculaphis* Del Guercio, Redia, v. 7, p. 461.

Characters.—Apterous form elongate; antennæ short, composed of five segments and situated on the under side of the head. Top of head forming a ledge which extends out over the antennæ forming an angle in front of the eye; eyes protruding. Cornicles large, very much swollen and curved, opening minute and flanged; cauda somewhat conical, rounded at the tip. Anal plate rounded; posterior part of abdomen extending out over the anal plate and somewhat over the cauda. Alate form with six-segmented antennæ armed with subcircular tuberculate sensoria. Fore wings with the media once branched, hind wings with both media and cubitus present. Cornicles somewhat slender, swollen, and slightly constricted at the tip. Cauda conical, not as long as the cornicles, anal plate rounded.

Type (monotypical), *Toxoptera caricis* Fullaway.

This genus is one of those peculiar genera, like *Aspidaphis* Gillette, which seem to be related to *Rhopalosiphum*.

Subtribe CERVAPHIDINA.

The subtribe Cervaphidina is a most interesting and peculiar one. The specialization is remarkable in that long processes are developed on the body and considerable reduction has taken place in the wings and antennæ while no Aphis-like cauda is found. Only two genera are known, which may be separated as follows:

KEY TO THE GENERA OF THE CERVAPHIDINA.

Cornicles swollen; body spine-like projections not armed with teeth... *Anomalaphis*.
 Cornicles not swollen; body spine-like projections armed with teeth.... *Cervaphis*.

Genus ANOMALAPHIS, n. gen.

Plate VIII, D-F.

Characters.—Body armed with elongate tubercle-like projections, particularly on the caudal portion; antennæ five-segmented in both apterous and alate forms, armed with subcircular sensoria. Fore wings with the media once branched; hind wings considerably reduced, with the cubitus absent. Cornicles distinctly swollen; cauda and anal plate reduced.

Type *Anomalaphis comperei* Pergande.*Anomalaphis comperei* Pergande, n. sp.

Among the many descriptive notes left by Mr. Theo. Pergande are some recording a peculiar species from Australia. This proves to represent an undescribed genus in the Cervaphidina. Pergande recognized the species as typical of a new genus to which he gave the manuscript name here used. He left no description of the genus and his notes on the species are given here exactly as he left them. The type is in the United States National Museum collection of Aphididae (Cat. No. 23065).

Feb. 18, 1907, Rec. from Compere, a lot of Aphides, found in 1901, on *Acacia* and *Eucalyptus*, along the beach at Albany, West Australia, which represents a new genus among Rhopalosiphins, and is a most remarkable Aphid in various respects. The antennæ, in the apterous and migratory female, are but 5-jtcd. while the spur is rather short and resembles that of *Chaitophorus*. The front wings are ample and reach considerably beyond the end of the body, with the third discoidal having but one fork, as in *Schizoneura*. The hind wings are very short and narrow and reach out to the apex of the 1st vein of the anterior wings, there is also but 1 discoidal, straight, and near the apex of the wing. The nectaries are short, clavate, and similar to those of *Siphocoryne*, the tail appears to be wanting. The abdomen of the migrant appears to have been of a dusky yellowish green, with transverse rows of small, black spots or tubercles, and blackish sutures between the segments. The eyes are brown; antennæ black, rather short, reaching barely to the abdomen and but 5-jointed; the two basal joints as usually; the 3rd joint is longest, about as long as the remaining joints together, including the spur, with some projecting sensoria and a few short hairs; joints 4 and 5 are subequal in length, exclusive of the spur, and clavate, the spur is about $\frac{1}{2}$ the length of the basal section of the joint, rather stout and blunt; the front of the head resembles that of *Aphis*. The sides of the abdominal segments are somewhat angulated, each angle provided with a very short, capitate, stout bristle, while at the posterior edge of the two segments, following the nectaries, there is a pair of long,

diverging, fleshy spines, with a sharp, quite long and slender spine at the tip; the posterior pair longest; all of them black; the end of the body is fringed with fine and quite long hairs. Legs as in other Aphides.

The apterous females are dark brownish or grayish green above, with a somewhat fusiform median, yellowish strip, broadest near the head, tapering posteriorly to a point and terminating in front of nectaries; the sutures of the segments, the sides and under side of the body are also of a yellowish color, on account of which, there is each side a subdorsal row of transverse, dark spots. The head and about basal half of the antennæ, dark, dirty yellowish, the eyes dark brown. There are about 4 short and curved capitate hairs on the front of the head and prominent fleshy tubercles each side of the body, each bearing at its apex a short, capitate spine or hair, all of them growing longer toward the nectaries, while beyond the nectaries there are two pairs of long and slender fleshy tubercles, tipped with a spine, as in the migrant. A tail could not be seen. In the younger forms and pupae, the tubercles are as in the apterous female. In the pupae the head, prothorax, abdomen and nectaries are of a dirty yellowish color, with transverse rows of small, black or dusky spots on the abdomen. The wing pads are black.

Genus CERVAPHIS Van der Goot.

Plate VIII, G.

1916. *Cervaphis* Van der Goot, Zur Kenntniss der Blattläuse Java's, p. 148.

Characters.—Body armed with a series of long toothed projections; antennæ of apterous form five-segmented, of the alate form six-segmented with somewhat oval sensoria. Fore wings with the media once branched; hind wings greatly reduced in size and lacking both the media and cubitus; cornicles elongate, subcylindric. Cauda and anal plate reduced. Oviparous females often winged.

Type (fixed by Van der Goot, 1916), *Cervaphis schoutedeniae* V. d. Goot.

Subtribe MACROSIPHINA.

The genera of the subtribe Macrosiphina may be separated at once from those of the Aphidina in that they have developed large antennal tubercles. These may assume various shapes by which the genera often may be separated. Considerable variation is met with also in the cornicles and cauda, although as a rule the cornicles are very well developed. They may be either cylindrical or swollen. In one genus, *Hyalopteroides* Theo., the cornicles are very short, suggesting some of the genera of the Aphidina. The cauda is as a rule rather long. The wings are in nearly every case normal in venation. The different genera may be separated by the following key:

KEY TO THE GENERA OF THE MACROSIPHINA.¹

- | | |
|--|----|
| 1. Cornicles swollen..... | 2. |
| Cornicles cylindrical or tapering, scarcely swollen..... | 6. |

¹ Since this paper was set up Takahashi (Insect World, v. 23, p. 439) has erected the following genus, which will fall in this subtribe.

Genus AKKAIA Takahashi.

Characters.—Cornicles swollen; frontal tubercles and first antennal segment with prominent projections. Antennæ of five segments. Cauda somewhat knobbed, anal plate large and projecting.

Type (monotypical), *Akkaia polygine*, Takahashi.

2. Cornicles cylindrical at base and extremity; abruptly swollen in middle. Rhopalosiphoninus.
Cornicles with the swelling gradual. 3.
3. Head with a large central process on vertex. Francoa. 4.
Head without this. 4.
4. Antennal tubercles large and diverging. 5.
Antennal tubercles converging; head and basal antennal segments with
very prominent capitate hairs. Capitophorus.
5. Cornicles much longer than cauda which is somewhat tapering. Amphorophora.
Cornicles about the length of cauda which is usually constricted near its
base. Megoura.
6. Cornicles very small, much smaller than the long, broad cauda. Hyalopteroides.
Cornicles as long as or longer than the cauda. 7.
7. Head with prominent, elongate projections to the antennal tubercles, par-
ticularly evident in the apterous form. Phorodon.
Head without these. 8.
8. Tubercles strongly converging. Myzus.
Tubercles distinctly diverging. 9.
9. Cornicles thick, about as long as the cauda which is large and somewhat
constricted near base. Macrosiphonella.
Cornicles very long, rather slender, subcylindric, somewhat tapering. 10.
10. Cauda elongate, constricted near base. Macrosiphum.
Cauda moderate or elongate, not constricted near base. 11.
11. First antennal segment and abdominal segments with long fingerlike tuber-
cles in the apterous form. Acanthaphis.
Without these. Illinoia.

Genus ACANTHAPHIS Matsumura.

Plate VII, R-U.

1918. *Acanthaphis* Matsumura, Trans. Sapporo Nat. Hist. Soc., v. 7, pt. 1, p. 15.The genus *Acanthaphis* Mats. is somewhat related to *Phorodon*.

Characters.—Head with prominent diverging antennal tubercles. Antennæ of six segments, first segment with a long fingerlike projection in the apterous form. Cornicles long, slender, and cylindrical. Cauda elongate, conical. Dorsum of abdomen with long fingerlike tubercles. Body with capitate hairs.

Type (fixed by Matsumura, 1918), *Acanthaphis rubi* Mats.

Genus AMPHOROPHORA Buckton.

Plate IV, A, B.

1876. *Amphorophora* Buckton, British Aphides, v. 1, p. 187.1886. *Macrosiphum* Oestlund, Minn. Geol. Survey Rept. 14, p. 27.1900. *Macrosiphum* Del Guercio, Nuove Rel. Staz. Firenze, ser. 1, no. 2, p. 159.1901. *Nectarosiphon* Schouteden, Ann. Ent. Soc. Belg., v. 45, p. 112.1913. *Eunectarostiphon* Del Guercio, Redia, v. 9, p. 188.1913. *Rhopalosiphum* Van der Goot, Tijd. voor Ent., v. 56, p. 146.

Buckton erected his genus *Amphorophora* for his *ampullata* which he had secured in the apterous form only. Oestlund gave the generic name *Macrosiphum* to a species he described as *rubicola*. In his second paper Oestlund describes a species under the name *ampullata* Buckton and says:¹ "The length of the antennæ, together with the distinct frontal tubercles, may justify our exception of *Amphorophora* as a good genus." In speaking of his *Macrosiphum*

¹ Bul. 4, Geol. and Nat. Hist. Surv. Minn., p. 77, 1887.

Oestlund says it may be too close to *Rhopalosiphum* and compares it with *nymphæae*. But had he compared it with *ampullata* which he also included in *Rhopalosiphum* he would probably have found it quite similar, and it is the writer's belief that Oestlund's species is in reality *Amphorophora*.

Finding that *Macrosiphum* was preoccupied Schouteden gave the new name *Nectarosiphon* to *rubicola* and *Nectarosiphon*, therefore, will become a synonym. In 1913, Del Guercio erected the genus *Eunectarosiphon* with *rubi* Kalt. as type. There appears not to be sufficient difference here, however. The insects are in their main points the same and *Eunectarosiphon* is placed, consequently, as a synonym. Van der Goot in the same year used *ampullata* as the type of *Rhopalosiphum*.

In 1900 Del Guercio used the name *Macrosiphum* for a genus including three species: *Convolvuli* Kalt., *viciae* Kalt., and *rubi* Kalt. He has since used both *viciae* and *rubi* as the types of other genera. This leaves only *convolvuli* in his *Macrosiphum*, and this species to all appearances is an *Amphorophora*. His *Macrosiphum*, therefore, is listed here under *Amphorophora*.

Characters.—Head with prominent and slightly diverging antennal tubercles. Antennæ of six segments, armed with circular sensoria. Wing venation normal. Cornicles long and somewhat swollen in the middle. Cauda elongate but much shorter than the cornicles.

Type (monotypical), *Amphorophora ampullata* Buckton.

Genus CAPITOPHORUS Van der Goot.

Plate VIII, A-C.

1913. *Capitophorus* Van der Goot, Tijds. voor Ent., v. 56, p. 84.

In the genus *Capitophorus* Van der Goot certain species suggest *Rhopalosiphum* in general characters, whereas others more nearly approach *Myzus* in their main characters. The capitate spines appear to be the best means of determining the genus.

Characters.—Head with antennal tubercles which are not markedly prominent, these each with one or more prominent knobbed spines. Vertex with a central projection on which similar spines are located. Antennæ of six segments, armed with subcircular sensoria, the first segment with a projecting process on which one or more knobbed spines are located. Wing venation normal; cornicles long and slender, slightly constricted in the middle and somewhat enlarged toward the distal extremity. Cauda rather short and conical.

Type (fixed by Van der Goot, 1913), *Aphis carduinus* Walker.

Genus FRANCOA Del Guercio.¹

1917. *Francoa* Del Guercio, Redia, v. 12, p. 201.

The genus *Francoa* Del Guercio appears very close in some respects to *Capitophorus* but on account of the peculiar frontal tubercle and the structure of the first antennal segment it is held to be distinct.

¹ It seems doubtful if this genus is distinct from *Capitophorus*. We have been unable to make a careful study of the type.

Characters.—Head with antennal tubercles present. Vertex with a prominent rectangular process, both the antennal tubercles and the frontal process armed with knobbed spines. Antennæ of six segments, the first segment lacking the process and capitate hairs of *Capitophorus*. Cornicles rather slender and swollen near the distal extremity. Cauda elongate, somewhat conical.

Type (monotypical), *Francoa elegans* Del Guercio.

Genus **HYALOPTEROIDES** Theobald.

1916. *Hyalopteroides* Theobald, The Entomologist, v. 49, p. 51.

The genus *Hyalopteroides* was erected by Theobald for his species *pallida* found in the nest of *Lasius niger*, Porlock Weir, Somerset. It bears a striking resemblance to *Pergandeidia* but there are no prominent antennal tubercles in that genus. However, there are slight swellings suggestive of those figured by Theobald. The writer has never seen specimens of *pallida* and therefore is unable to give a personal opinion. Theobald says, "Head with marked frontal tubercles." This would place the genus as not closely related and pending a study of specimens it may be left thus.

Characters.—Head with prominent antennal tubercles. Antennæ of six segments and armed with subcircular sensoria. Cornicles subcylindric, short, much shorter than cauda. Cauda long and conical.

Type (monotypical), *Hyalopteroides pallida* Theo.

Genus **ILLINOIA** Wilson.

Plate VIII, H-J.

1910. *Illinoia* Wilson, Ann. Ent. Soc. Am., v. 3, p. 318.

1914. *Metopeurum* Mordwilko, Faune de la Russie, Hemiptera, v. 1, p. 56, 67.

1914. *Acyrtosiphon* Mordwilko, Faune de la Russie, Hemiptera, v. 1, p. 55, 62.

This genus is closely related to *Macrosiphum* Pass. from which it may be distinguished by the nature of the cauda.

Characters.—Head with prominent diverging frontal tubercles. Antennæ of six segments armed with subcircular sensoria. Fore wings with the media twice branched, hind wings with both media and cubitus present. Cornicles cylindrical, sometimes slightly larger toward the middle which appearance is accentuated by a constriction often present near the distal extremity. Cauda conical, not as in *Macrosiphum* with a constriction near its base. Males usually winged, oviparous females apterous.

Type (fixed by Wilson, 1910), *Siphonophora liriiodendri* Mon.

Genus **MACROSIPHONIELLA** Del Guercio.

Plate VIII, R-T.

1911. *Macrosiphoniella* Del Guercio, Redia, v. 7, p. 331.

1913. *Macrosiphum* Van der Goot, Tijds. voor Ent., v. 56, p. 145.

1914. *Dicelysmura* Mordwilko, Faune Russ. Aphidodea, p. 56.

The genus *Macrosiphoniella* was erected by Del Guercio with *atrum* Ferr. as type. In 1913 Van der Goot used *Macrosiphum* of Passerini, indicating *millefolii* Fab. as type. This species can not be made the type of *Macrosiphum* Pass., and since it is essentially like *atrum*, V. d. Goot's *Macrosiphum* must become a synonym of *Macrosiphoniella*. In 1914, Mordwilko used the generic name *Dicelysmura* for *millefolii* and figured the species. This name then proves also to be a synonym.

Characters.—Head with prominent diverging antennal tubercles. Antennæ of six segments armed with subcircular prominent sensoria. Fore wings with the media twice branched, hind wings with both media and cubitus present. Cornicles short, about the length of the cauda and rather thick, usually with conspicuous polygonal markings; cauda large, slightly constricted near the base.

Type (fixed by Del Guercio, 1911), *Aphis atrum* Ferr.

Genus MACROSIPHUM Passerini.

Plate VIII, U-W.

- 1860. *Macrosiphum* Passerini, Gli Afidi, p. 27.
- 1855. *Siphonophora* Koch, Die Pflanzenläuse Aphiden, p. 150.
- 1887. *Nectarophora* Oestlund, Minn. Geol. Survey Bul. 4, p. 78.
- 1913. *Macrosiphon* Del Guercio, Redia, v. 9, p. 188.

In 1855 Koch used the generic name *Siphonophora* for this genus for which Passerini substituted *Macrosiphum*. Not aware of this Oestlund, seeing that *Siphonophora* was preoccupied, substituted *Nectarophora* and strangely enough used *Macrosiphum* for another genus in a different sense. Del Guercio uses *Macrosiphon* in this sense.

Characters.—Head with prominent diverging frontal tubercles. Antennæ of six segments, armed with subcircular sensoria. Fore wings with the media twice branched; hind wings with both media and cubitus present. Cornicles long, subcylindrical, mostly somewhat tapering; cauda long, somewhat constricted about the middle. Sexes with the male usually alate and the oviparous form apterous.

Type (fixed by Passerini, 1860), *Aphis rosae* Linn.

Genus MEGOURA Buckton.

- 1876. *Megoura* Buckton, British Aphides, v. 1, p. 188.
- 1913. *Drepaniella* Del Guercio, Redia, v. 9, p. 188.

The genus *Megoura* Buckton is similar to *Amphorophora* in that prominent antennal tubercles are present. It differs, however, in that the cornicles are short, about equal in length to the cauda. Buckton erected the genus for his *viciae* which Schouteden considered the same as *viciae* Kalténbach. It certainly is very similar in every respect.

Viciae Kalt. was set as the type of his genus *Drepaniella* by Del Guercio, therefore *Drepaniella* will become a synonym of *Megoura*.

Characters.—Head with distinct antennal tubercles. Antennæ of six segments, armed with subcircular sensoria. Wing venation normal; cornicles moderately long and swollen in the middle. Cauda about the same length as the cornicles.

Type (monotypical), *Megoura viciae* Buckton.

Genus MYZUS Passerini.

Plate VIII, L, M, X-Z.

- 1860. *Myzus* Passerini, Gli Afidi, p. 27.
- 1860. *Rhopalosiphum* Passerini, Gli Afidi, p. 27.
- 1913. *Myzoides* Van der Goot, Tijd. voor Ent., v. 56, p. 84.
- 1913. *Ovatus* Van der Goot, Tijd. voor Ent., v. 56, p. 84.
- 1914. *Myzodes* Mordwilko, Faune Russ. Aphidoidea, p. 52.
- 1914. *Aulacorthum* Mordwilko, Faune Russ. Aphidoidea, p. 58.
- 1916. *Ncomyzus* Van der Goot, Zur Kennt. der Blattläuse Java's, p. 50.
- 1918. *Myzopsis* Matsumura, Trans. Sapporo Nat. Hist. Soc., v. 7, pt. 1, p. 19.

The genus *Myzus* was erected with *Aphis cerasi* Fab. as type. In the same year Passerini used *Aphis persicae* Sulz. as type of *Rhopalosiphum* Koch. *Aphis nymphaeae* L., however, had been set as the type of that genus in 1856. *Persicae* seems to be very closely related to *cerasi* and *Rhopalosiphum* (Koch) Pass., therefore, is placed as a synonym of *Myzus*.

In 1913 Van der Goot placed certain other species in *Myzus* and the type of the genus he made the type of his *Myzoides*. This will evidently then become a synonym, as it has the same type.

In 1916 Van der Goot erected the genus *Neomyzus* with *circumflexum* Buckt. as type. While the frontal tubercles of this species do not converge quite to the same extent as those of *cerasi*, they are quite similar and the cauda is somewhat conical as in that species. *Neomyzus*, therefore, is believed to be a synonym. Mordwilko used the name *Myzodes* with *tabaci* Mord. as type. This species he does not fully describe, but gives a figure and describes the characters of the genus. From the information given it appears to be a synonym of *Myzus*. The writer also believes that the genus *Ovatus* V. d. Goot is a synonym of *Myzus*. This genus was erected with *mespili* V. d. Goot as type. The genus *Aulacorthum* Mord. was erected with *pelargonii* as type. A study of this species shows the antennal tubercles very similar to those of *cerasi*. The cornicles, too, are quite similar, although the cauda is a little more *Aphis*-like. The writer believes this genus is a synonym.

Characters.—Head with distinct antennal tubercles present which, particularly in the apterous form, project inward and are strongly gibbous. Antennae of six segments, the first segment gibbous like the antennal tubercles. Wing venation normal. Cornicles rather long and subcylindrical. Cauda somewhat short and conical, constricted very slightly, if at all.

Type (fixed by Passerini, 1860), *Aphis cerasi* Fab.

Genus **PHORODON** Passerini.

Plate VIII, N-Q.

1860. *Phorodon* Passerini, Gli Afidi, p. 27.

Characters.—Head in the alate form with distinct antennal tubercles which project somewhat inward, first antennal segment gibbous. In the apterous form the antennal tubercles possess very prominent projections which extend forward in front of the head. First antennal segment with a projecting process. Fore wings with media twice branched; hind wings with both media and cubitus present. Cornicles cylindrical, in the apterous form somewhat curved; cauda rather acutely conical, not as long as the cornicles.

Males as a rule winged and oviparous females apterous.

Type (fixed by Passerini, 1860), *Aphis humuli* Schrk.

Genus **RHOPALOSIPHONINUS**, n. gen.

Plate IV, D-F.

The genus *Rhopalosiphoninus* is erected for *latysiphon* Davidson, a species with very peculiar cornicles. It appears to be somewhat related to *Amphorophora*.

Characters.—Head with prominent antennal tubercles which project inward and are armed with prominent spines. Antennae of six segments armed with subcircular sensoria and in the first segment with spines similar to those of the antennal tubercles. Wing venation normal. Cornicles narrow and cylindrical at the base, then abruptly and prominently swollen, returning again abruptly to the normal size near the tip. Cauda rather short and conical.

Type, *Amphorophora latysiphon* Davidson.

Subtribe PENTALONINA.

The subtribe Pentalonina is one of the Aphidini in which specialization in the wing venation has taken place in a peculiar manner. The radial sector has in one genus extended downward and coalesced with the upper branch of the media. In the genus *Idiopterus* the two have not become entirely fused, though in some specimens they have almost done so. In Pentalonia, however, the veins have become permanently united, and a very peculiar-looking venation is the result. A closed cell is formed by the radial sector when it meets the upper branch of the media, and when it leaves this again it gives a three-branched appearance to the upper branch of the media. The explanation of this peculiar venation is, however, easily understood by comparison with the venation of *Idiopterus*. In some of the genera the hind wings are greatly reduced, so that sometimes only one vein remains, while in other genera this reduction has not taken place. Most of the wing veins are clouded with brownish borders.

The insects feed usually upon ferns or tropical plants.

KEY TO THE GENERA OF THE PENTALONINA.

- | | |
|--|---------------|
| 1. Hind wings much reduced in size, lacking at least the cubitus | 2. |
| Hind wings nearly normal in size and with both media and cubitus present. | 3. |
| 2. Radial sector of fore wing fused with the upper branch of the media, forming a closed cell..... | Pentalonia. |
| Radial sector of fore wings not so fused, but normal | Microparsus. |
| 3. Cornicles cylindrical..... | Idiopterus. |
| Cornicles somewhat swollen near their distal extremities..... | 4. |
| 4. Media of fore wings twice branched..... | Fullawayella. |
| Media of fore wings once branched..... | Neotoxoptera. |

Genus FULLAWAYELLA Del Guercio.

1911. *Fullawayella* Del Guercio, Redia, v. 7, p. 462.

1916. *Micromyzus*, Van der Goot, Zur Kenntniss der Blattläuse Java's, p. 55.

This genus is very suggestive of *Amphorophora* in certain ways but no doubt is related here. Van der Goot's genus was erected with *nigrum* V. d. Goot as type but this species differs very little from *kirkaldyi*.

Characters.—Antennae on prominent, converging, imbricated antennal tubercles, of six segments and armed with subcircular sensoria. Fore wings with the media twice branched and with the radical sector deeply curved toward the upper branch of the

media; hind wings with both media and cubitus present. Cornicles somewhat swollen near their distal extremities. Cauda elongate and constricted near the base.

Type (monotypical), *Macrosiphum kirkaldyi* Fullaway.

Genus **IDIOPTERUS** Davis.

Plate VIII, EE-HII.

1900. *Idiopterus* Davis, Ann. Ent. Soc. Amer., v. 2, p. 198.

Idiopterus, a less specialized genus than *Pentalonia*, is worthy of special note, as it gives a key to the peculiar venation of the latter genus. The coalescing of the radial sector and the media is here plainly visible and in some specimens a triangular closed cell is formed, although in most examples the two veins can be traced distinctly.

Characters.—Head with prominent antennal tubercles which project slightly inwards, and are gibbous. Antennæ of six segments, armed with subcircular sensoria, the first segment gibbous like the antennal tubercles. Cornicles subcylindric, rather slender, cauda somewhat elongate, conical. Fore wings with the radial sector extending abruptly downward from the stigma and paralleling the upper branch of the media with which in some specimens it appears to be almost united; hind wings with both media and cubitus present.

Type (monotypical), *Idiopterus nephrolepidis* Davis.

Genus **MICROPARSUS** Patch.

Plate VIII, AA-DD.

1909. *Microparsus* Patch, Ent. News, v. 20, p. 337.

Microparsus is at once distinguished from the other genera related to it by the peculiar venation and the reduction of the hind wing.

Characters.—Head with distinct antennal tubercles present. Antennæ of six segments, armed with subcircular sensoria. Fore wings with the media once branched; hind wings much reduced in size and lacking both the media and cubitus. Cornicles subcylindric. Cauda rather long and tapering, almost equal in length to the cornicles.

Type (monotypical), *Microparsus variabilis* Patch.

Genus **NEOTOXOPTERA** Theobald.¹

1915. *Neotoxoptera* Theobald, Bul. Ent. Res., v. 6, p. 131.

This genus is closely related to *Fullawayella*, from which it can be separated by the venation. There has been some doubt whether or not this is a good genus, for the name will not hold if the type is found to correspond with Pergande's *violae*, which it resembles. In that case *Neotoxoptera* would become a synonym of *Fullawayella*, for Pergande's species is undoubtedly a *Fullawayella*.

Characters.—Head with prominent antennal tubercles. Antennæ of six segments, armed with subcircular sensoria. Fore wings with the media once branched. Cornicles swollen, elongate, somewhat conical.

Type (monotypical), *Neotoxoptera violae* Theo.

¹ After this paper was in type the writer (Bul. Ent. Res., v. 10, p. 45) showed that *violae* Theo. is a synonym of *violae* Perg.

Genus *PENTALONIA* Coquerel.

Plate VIII, II-MM.

1859. *Pentalonia* Coquerel, Ann. Ent. Soc. France, Ser. 3, v. 7, p. 259.

The genus *Pentalonia* Coquerel is a very peculiar one and possesses a venation unlike that of any other in the Aphididae. It is, however, only a little further development of the condition met with in *Idiopterus*, which is the less specialized of the two genera.

Characters.—Head with prominent antennal tubercles which are, more especially in the apterous form, projected inward, gibbous and somewhat Myzus-like in appearance. Antennae of six segments; armed with subcircular sensoria, the first segment gibbous like the antennal tubercles. Cornicles somewhat constricted near their middle, then again somewhat swollen near their distal extremity. Cauda rather small but elongate, subconical, slightly constricted about the middle. Fore wings with the radial sector extending abruptly downward and meeting the upper branch of the media with which it fuses but is diverted again toward its natural course near the tip of the wing. A closed cell is thus formed by the radial sector and the media but at the margin of the wing there are the same veins as in the Aphidini (Plate VIII, JJ.) Hind wings very much reduced, cubitus absent.

Type (monotypical), *Pentalonia nigronervosa* Cq.

Subfamily II, MINDARINAE.

It has been the custom to consider the genus *Mindarus* as closely related to the Pemphigini, but the writer is unable to do this and concludes that it must represent a subfamily in itself. In some ways *abietinus* is the most primitive living aphid. It is, in fact, the only one which has retained the general wing structure which is predominant in the fossil forms. It is true that the venation is more reduced than in some of the other subfamilies, but the type of wing in regard to the stigma formation is exactly like most fossil wings and unlike the wings of other living forms. Many of the characters suggest the Eriosomatinae and the genus is no doubt very similar to the ancestors of the insects in that subfamily. The antennal structure and general form are like those in the Eriosomatinae. The sexes, too, are apterous, but though they have developed the small apterous condition they are in many ways more primitive than are the sexes of the Eriosomatinae. The male is small and suggests the condition in those forms. The peculiar habit of copulation is similar, in that the male mounts the female and may remain there inactive for a very long period. The writer has observed a male of *Eriosoma lanigerum* clinging thus to a female for 48 hours. The sexes of *Mindarus*, however, have not lost the beak and the male feeds on the juices of its host. In this regard they are more primitive than sexes in the Eriosomatinae. The oviparous female, moreover, develops her ovaries and produces as high as 8 or 9 eggs, in striking contrast with the ovipara in the Eriosomatinae. It is a much less specialized condition. In regard to the alate form the shape of the cauda is quite different from that met with in the Eriosomatinae.

It seems to the writer that the Mindarinae give a fair idea of the ancestors of the Eriosomatinae and may even represent a group dominant in earlier times from which the Eriosomatinae sprang.

Only one genus is represented.

Genus MINDARUS Koch.

Plate IX, A-F.

1857. Koch, Die Pflanzenläuse Aphiden, p. 277.

The peculiar genus Mindarus was erected by Koch with *abietinus* Koch as type. This species is the only one in the genus, although it has been redescribed as *Schizoneura pinicola* Thos. and *Schizoneura obliqua* Chol.

Characters.—Cornicles present as mere rings. Large wax plates present. Alate forms with six-segmented antennae armed with oval sensoria. Fore wings with the media once branched; radial sector inserted mesad of the long narrow stigma, thus giving a very long stigmal cell; hind wings with both media and cubitus present. Cauda rather long, not rounded, but somewhat conical or even spatulate. Sexes small and apterous, beaks present and feeding taking place. Oviparous female with the ovaries developed and laying as high as 9 eggs. Forms living free upon the twigs of conifers which become somewhat distorted by the feeding of the insects.

Type (monotypical), *Mindarus abietinus* Koch.

Subfamily III, ERIOSOMATINAE.

The subfamily Eriosomatinae is composed of insects which are perhaps as specialized as any of the Aphididae. They show a remarkable development of the habit of gall formation and in this respect parallel the Hormaphidinae. The insects of that subfamily, however, evidently have developed the habit independently. Many previous authors have placed all of these forms in the present subfamily. This, the writer believes, is incorrect, as shown by the biologies of the insects. The sexual forms give a true understanding of the relationships and of the genera which should be included in the Eriosomatinae. All of the forms included by the writer show evidence of a common origin in that the sexes have become degenerate. They have become small apterous forms and have lost the mouth parts and the ability to take food. That this was not their original condition is clearly shown by the history of the family and also by the fact that the sexual forms of some species have a beak when born, but lose this at the first molting. Other species even at the time of birth are devoid of all but a rudimentary trophictubercle. The reproductive system of the female has become greatly altered. As previously pointed out by the writer, the early development of the reproductive system of the sexual female corresponds exactly to that in the apterous forms and to that of the oviparous forms of the more primitive groups.

Young embryos * * * show that the ovaries are at first similar to those of the parthenogenetic form. There may be distinguished the four chambers on each side containing egg cells and nutritive cells. In later embryos most of the egg tubes are in

the process of degeneration and only two ovaries, one on each side, develop. Of these one finally degenerates and the egg of the other grows until it fills almost the entire body and the insect appears to be little else than egg.¹

It will be seen at a glance that such a method of egg development is entirely different from that met with in members of the genera which have been heretofore placed in the subfamily. The Hormaphidini and the Thelaxini, as will be seen under the discussion of those tribes, have sexual females which develop normal ovaries and lay several eggs in the same way as do the Aphidini, Lachnini, and other groups. It is true that some have developed gall formation and highly specialized, wax-secreting organs, but this is more of a parallelism than a close relationship, as is indicated by the sexual forms. The wax-secreting organs of the Eriosomatinae vary considerably in structure. A study of those in the genus *Eriosoma* has been presented by the writer (1915). The glands here are compound, each cell containing a central wax chamber into which the wax is secreted and from which it is forced out as a fine waxen thread. In other genera the wax glands take on the nature of plates, illustrated in the genus *Prociphilus*. These glands are essentially the same in general structure as are those in *Eriosoma*, but the wax cells are placed very close together and are so extremely elongate that their openings to the surface are very small. A large number of these gives the appearance of a more or less uniform plate. The structure, however, in the two genera follows the same lines.

The wing venation in this subfamily presents as great a reduction as in any of the subfamilies of the Aphididae and in this respect it is comparable to the Hormaphidinae. In the fore wings the reduction is shown in the media which is never branched more than once. Dr. Patch has pointed out the homologies of the veins and has indicated that in all of these cases the branches represent M_{1+2} and M_{3+4} . In some cases, however, it would appear as if they were M_1 and M_4 . In other genera the media is indicated as a single vein. The radial sector is in nearly every case present and the cubitus and first anal are prominent veins. The tracheae are figured for the subfamily under the genus *Eriosoma*. In the hind wings the radial sector is always present and two oblique veins are nearly always found. These are the media and the cubitus. In several genera, however, the cubitus has disappeared and only the media remains as the one transverse vein in the hind wings.

The cornicles in the genera of this subfamily are not prominently developed. Indeed, they are absent altogether in certain of the tribes. In the genus *Eriosoma* they are chitinized rings slightly elevated on shallow hairy cones. The opening of the cornicles is closed by a muscle and from the cornicle a narrow duct leads to a

¹ Baker, A. C. The woolly apple aphid. U. S. Dept. Agr., Off. of Sec., Rept. 101, p. 43. 1915.

large wax reservoir. The structure of the cornicles themselves in this subfamily is essentially the same in all genera where they are present. In a large number of genera, however, the wax reservoir is absent and in some specialized tribes the cornicles are likewise absent. It is interesting to note that in some genera, though absent in the stem mother, they are present in the alate forms.

The habit of gall formation is not found equally in all genera and it would seem that those forms which have become associated with ants have not developed this habit to the same extent as have some of the other groups. However, it must be borne in mind that our knowledge concerning the species associated with ants is very incomplete, and the writer is convinced that many of the Prociphilini will be found during their summer generations in this relation. Many of the forms cause true galls which are the result of outgrowths of the plant and which completely enclose the insects. Sometimes the stem mother lives in a gall by herself while in other cases the following generations live with her. The original spring gall is usually the result of the activities of the young stem mother. Certain species do not produce true galls but form pseudogalls which are due to the rolling or crumpling of the leaves on which the insects feed. Other species, again, especially during their summer generations, feed on the twigs or roots of plants and give rise to excrescences by their feeding. It often happens that species which in their spring forms are gall makers, attack plants in this way in their summer generations. Others live on the roots of grasses during these generations and do not cause the excrescences produced by those species feeding on trees and woody shrubs.

The association with ants is highly developed by one tribe of this subfamily, although all of the other tribes are to a degree tended by these insects. The species of the Fordini live exclusively in the nests of ants or are tended by them, and they are cared for very carefully in return for the honeydew excreted. Ants also attend species which have aerial feeding habits and they may be seen carrying the root generations of species of *Eriosoma* from one place to another and even distributing them about on the trees. Indeed the writer once took advantage of the presence of ants to infest some apple seedlings. A vial of apterous insects was emptied at the base of each tree and the ants soon could be seen running about carrying the aphids to suitable positions on the trees. Sometimes, however, they carried them away.

KEY TO THE TRIBES OF THE ERIOSOMATINAE.

1. Cornicles present, at least in the alate forms; however, often mere rings.... 4.
Cornicles absent..... 2.
2. Forms living in true galls or in pseudogalls on plants..... 3.
Forms living in the nests of ants or at least subterranean, feeding on the roots of plants; wax-secreting areas present; antennæ of alate forms rather short and thick with somewhat oval sensoria..... FORDINI.
3. Forms living in true galls and without wax plates prominently developed on the head and thorax of alate form; wax-secreting areas present but not prominently developed. Alate forms leaving the galls in the late summer or fall. Antennæ with annular sensoria MELAPHINI.
Forms living in pseudogalls, occasionally in true galls. Antennæ of alate form rather long and slender, with narrow or somewhat oval or rounded sensoria. Wax plates well developed and present on the head and thorax of the alate forms which leave the galls in the spring..... PROCIPHILINI.
4. Forms living in galls, pseudogalls, or free upon their host; wax glands prominently developed; antennæ of alate forms armed with annular sensoria which almost completely encircle the segments..... ERIOSOMATINI.
Forms living usually in true galls; wax glands present but not strongly developed; antennæ of alate forms armed with narrow, transverse sensoria, somewhat oval or irregular ones, or occasionally without sensoria.. PEMPHIGINI.

Tribe ERIOSOMATINI.

The tribe Eriosomatini is composed of insects which have more or less developed the habit of gall formation, which are possessed of wax glands, and the antennæ of the alate forms of which are armed usually with annular sensoria. Their typical host group is that of the elms.

Characters.—Forms living in galls, pseudogalls, or free upon the twigs or roots of their host on which they form excrescences. Prominent wax glands present. Cornicles distinct; antennæ of alate forms armed with annular sensoria which often almost completely encircle the segments. Sexual forms small, apterous, beakless; oviparous females developing a solitary egg.

KEY TO THE GENERA OF THE ERIOSOMATINI.

1. Media of the fore wings of alate form once branched..... 3.
Media of the alate form simple..... 2.
2. Hind wings with both media and cubitus present..... Gobaishia.
Hind wings with only the media present..... Tetraneura.¹
3. Hind wings with both media and cubitus present..... Eriosoma.
Hind wings with only the media present..... 4.
4. Stem mother with four-segmented antennæ; antennæ of alate form rather short and thick..... Colopha.
Stem mother with five-segmented antennæ; antennæ of alate form long and slender..... Georgia.

¹ There is considerable evidence for separating a tribe Tetraneurini to include the genera Colopha, Tetraneura, and Gobaishia.

Genus *COLOPHA* Monell.

Plate IX, G-L.

1877. *Colopha* Monell, Can. Ent., v. 9, p. 102.

The genus *Colopha* was erected for *ulmicola* Fitch. One of the principal characters whereby it may be separated from *Tetraneura* is the once-branched character of the media. The two genera, however, are very closely related. The species have the same peculiar structure and the same mode of life.

Characters.—Cornicles slightly elevated rings. Stem mother with four-segmented antennæ. Apterous form with five-segmented or sometimes six-segmented antennæ. Wax glands present. Alate form with six-segmented antennæ which are armed with annular sensoria partly encircling the segments. Fore wings with the media once branched, hind wings with only the media present. Forms making galls upon the leaves of trees in which the stem mother and her offspring live in company; in summer migrating to the roots of plants.

Type (monotypical), *Byrsocrypta ulmicola* Fitch.Genus *ERIOSOMA* Leach.

Plate IX, M-T.

1818. *Eriosoma* Leach, Trans. Hort. Soc. London, v. 3, p. 60.1831. *Myzoxylus* Blot, Mem. Soc. Roy. Agr. et de Com. Caen., v. 3, p. 332.1837. *Schizoneura* Hartig, Jahresb. ü. d. Fortschr. d. Forstwiss. und forstl. Naturk., v. 1, p. 645.1848. *Mimaphidus* Rondani, Nuovi Annali della Scienze Naturali, ser. 2, v. 9, p. 35.

In 1818 Leach erected his genus in a footnote in connection with a paper read by Mosley. The paper was published in 1818. In 1819 Samouelle published his "Useful Compendium" and on page 232 characterized the genus *Eriosoma* Leach MSS. The printed copy of the Transactions appeared complete in 1820. In 1824 Blot used the word *Myzoxyle* which he corrected to *Myzoxylus* in 1831. For these *Aphis lanigera* Hausm. was used as type.

In 1837 Hartig erected *Schizoneura* and of this genus *ulmi* was made type by Passerini in 1860. This then will become a synonym. *Corni* Fab. was for a time considered the type of this genus but this species was not in the original genus. In 1848 Rondani used *Mimaphidus* with *ulmi* Fab. as type, which according to Passerini is the same as *lanuginosa* Hartig. Therefore, this genus will become a synonym.

Characters.—Cornicles distinct rings on somewhat elevated tubercles. Apterous form with six-segmented antennæ. Stem mother with five-segmented antennæ. Wax plates present in the apterous and alate vivipara. Alate form with six-segmented antennæ armed with annular sensoria. Fore wings with the media once branched, hind wings with both media and cubitus present; cauda and anal plate rounded. Forms living in gall-like formations or causing excrescences on their hosts. Sexual forms small, apterous, beakless. Only one egg of those of the oviparous female develops.

Type (monotypical), *Aphis lanigera* Hausmann.

Genus GEORGIA Wilson.

Plate IX, U-Z.

1911. *Georgia* Wilson, Can. Ent., v. 43, p. 64.

The genus *Georgia* appears to be related to *Colopha* Mon., and yet many of the characters are so like those of *Eriosoma* that the insect suggests that genus also. Especially to the species *E. americanum* Riley there is a striking resemblance. Prominent wax glands are lacking but these are sometimes also lacking in the spring forms of *Eriosoma*.

Characters.—Cornicles present and situated on shallow hairy cones as are those of *Eriosoma*. Stem mother with five-segmented antennæ; alate form with six-segmented antennæ which are armed with narrow sensoria that do not encircle the segment to any extent. Fore wings with the media once branched, hind wings with only one oblique vein. Cauda rounded. Prominent wax pores such as those present in *Eriosoma* lacking, but small wax areas present.

Forms living in pseudogalls on plants, the alate individuals migrating from the galls in the early spring.

Type (monotypical), *Georgia ulmi* Wlson.

Genus GOBAISHIA Matsumura.

Plate X, A-G; XI, V.

1909. *Byrsocrypta* Tullgren, Arkiv för Zoologi, Bd. 5, no. 14, p. 182.1917. *Gobaishia* Matsumura, Synopsis of the Pemphigidae of Japan, Gifu, Japan, p. 75.

Tullgren used the name *Byrsocrypta* Hal. as the name of a subgenus with *pallida* as type, placing it under *Tetraneura*. He apparently overlooked the fact that Westwood had set *bursarius* as the type of the genus *Byrsocrypta* as will be found discussed under the genus *Pemphigus*. *Pallida* is different from the species of *Tetraneura*, in that the cubitus is retained in the hind wing. If *Colopha* is retained on account of the branched nature of the media in the fore wings it will be necessary to place *pallida* as typical of a genus related to *Tetraneura*.

In 1917 Matsumura erected the genus *Gobaishia* with *Gobaishia japonica* Mats. as type. This species was stated to be very similar to *Tetraneura alba* Ratz. *Tetraneura alba* Ratz is the same species as *Eriosoma pallida* Haliday and the characters given for the genus are, therefore, similar to Tullgren's conception of *Byrsocrypta*. The figures drawn are from specimens of *pallida* as no *japonica* was available to the writer for study.

Characters.—Cornicles present, stem mother with four-segmented antennæ, alate forms with six-segmented antennæ which are armed with annular sensoria. Fore wings with the media usually simple; hind wings with both cubitus and media present.

Type (fixed by Matsumura, 1917), *Gobaishia japonica* Mats.

Genus TETRANEURA Hartig.

Plate X, H-M.

1841. *Tetraneura* Hartig, Germar's Zeitschrift für die Entomologie, v. 3, p. 366.

In 1841 Hartig erected the genus *Tetraneura* under which he gave *Tetraneura ulmi* Lin. ? questioned thus and described. He also listed *T. rugicornis* Hartig. One of these species was questioned and the other merely listed. *Ulm* L., however, was questioned only in the sense of the determination, and a good description was given so that it is known what insect Hartig had.

In 1843 Kaltenbach gave a description of the genus *Tetraneura* crediting it to Hartig and described thereunder one species, *Aphis ulmi* De Geer. *Aphis ulmi* De Geer (1773) is the same species as *Aphis ulmi* Geoffroy (1764) but this name can not be used, since Linnaeus used *Aphis ulmi* for a different insect. This is the same insect described by Hartig as *T. ulmi* L. ? and it is evident that it requires a new name, to which *ulmifoliae* is given.

Characters.—Cornicles very slightly elevated rings, not at all prominent. Stem mother with four-segmented antennæ; apterous form with five-segmented antennæ. Wax glands present. Alate form with six-segmented antennæ which are armed with narrow annular sensoria almost completely encircling the segment. Fore wings with the media simple; hind wings with only the media present.

Forms living in galls and migrating in spring to other plants. Sexes small, apterous and beakless. Oviparous female developing only one egg.

Type, *Tetraneura ulmifoliae* Baker (*Aphis ulmi* L. of Hartig).

Tribe PEMPHIGINI.

The tribe Pemphigini is composed of forms which are highly specialized and most of which have developed the habit of true gall formation. The secretion of wax also occurs but wax secreting plates are not developed to the extent met with in some of the other tribes of the subfamily. Alternation of hosts is found to occur, migrants leaving the galls in early spring or summer and returning in autumn. In some species, however, the insects do not leave the galls until the mothers of the sexual forms are produced. Distinct cornicles are present and by this character forms in some of the other tribes which are suggestive of the Pemphigini may be distinguished. The typical host group is *Populus* and the galls are normally spring galls.

Characters.—Forms usually inhabiting true galls and often migrating to other plants during the summer. Antennæ of six segments in the alate form and in nearly all genera armed with linear, oval, or somewhat irregularly shaped sensoria. Small wax-secreting areas present. Sexual forms small, apterous, and beakless, the oviparous female developing only one egg.

Six genera may be included in the tribe and these genera may be separated by the following key:

KEY TO THE GENERA OF THE PEMPHIGINI.

1. Unguis of segment VI of alate form distinctly long and Aphis-like...Mordwilkoja.
Unguis short and knob-like..... 2.
2. Media once branched..... 3.
Media simple..... 4.
3. Antennæ of alate form usually without secondary sensoria. Wings flat
in repose.....Phloeomyzus.
Antennæ of alate form with secondary sensoria. Wings not flat in repose
.....Pachypappella.
4. Both media and cubitus present in hind wing..... 5.
One oblique vein only in hind wing.....Dryopeia.
5. Antennæ of alate form without secondary sensoria. Wings flat in repose
.....Rhizoctonus.
Antennæ of alate form with secondary sensoria. Wings not flat in repose... 6.
6. Antennæ of alate form rather short and thick. Stem mother with four-seg-
mented antennæ.....Pemphigus.
Antennæ of alate form rather long and slender. Stem mother with five-seg-
mented antennæ.....Cornaphis.

Genus CORNAPHIS Gillette.

Plate X, N-T.

1913. *Cornaphis* Gillette, Ann. Ent. Soc. Am., v. 6, p. 491.

The genus *Cornaphis* was erected by Gillette for his species *Cornaphis populi*. In his description it is stated that the genus is closely related to *Asiphum*. In *Cornaphis*, however, there are large cornicles in the alate form and in other respects it seems that the genus is closely related to *Pachypappella*. In that genus, however, the media is once forked, whereas in *Cornaphis* it appears to be simple, at least as a rule. This difference has led the writer to retain a genus with *lactea* as type rather than to place that species and similar ones in *Cornaphis*.

Characters.—Cornicles present; stem mother with five-segmented antennæ and without wax plates. Alate form with six-segmented antennæ armed with rather narrow sensoria; permanent sensoria ciliate. Fore wings with the media simple, hind wings with both media and cubitus present; wax plates present in the apterous form; sexes small, apterous and beakless; the oviparous female developing only one egg.

Forms living in galls, the stem mother and the following forms living in the same gall.

Type (monotypical), *Cornaphis populi* Gill.

Genus DRYOPEIA Kirkaldy.

Plate X, U-Y.

1857. *Endeis* Koch, Die Pflanzenläuse Aphiden, p. 312.

1889. *Endeis* Ashmead, Ent. Amer., v. 5, p. 189.

1904. *Dryopeia* Kirkaldy, The Entomologist, v. 37, p. 279.

1917. *Watabura* Matsumura, Synopsis of the Pemphigidae of Japan, p. 89.

In 1857 Koch erected his genus *Endeis* with two species, *bella* Koch and *rorea* Koch. This name was replaced by *Dryopeia* in 1904 by Kirkaldy, and *bella* has been definitely placed as the type.

In some respects the genus is suggestive of *Anoecia*, although it seems to be undoubtedly a Pemphiginid and will no doubt be so proven by the sexual forms.

In 1917 Matsumura erected his genus *Watabura* with *Watabura nishiyae* Mats. as type. This species was stated to resemble a Pemphigus, excepting that the antennal segments are somewhat different and only one oblique vein is in the hind wing. (Two obliques are shown in his Pl. XII, 9). The antennae are armed with narrow transverse sensoria and there seems little doubt that this genus is a synonym of *Dryopeia*. It is noteworthy that the life history of the type species is not known, but it is thought to live on the roots of trees. The type of the genus *Dryopeia* is a root feeder.

Characters.—Cornicles present, situated on broad shallow cones, suggestive of those of *Anoecia*. Stem mother unknown, apterous forms with six-segmented antennae. Alate forms with six-segmented antennae, armed with narrow transverse sensoria. Fore wings with media simple, hind wings with one oblique vein. Summer forms subterranean, living on the roots of plants. Spring forms and sexes unknown. Apterous tarsi one-segmented.

Type (fixed by Kirkaldy, 1906), *Endeis bella* Koch.

Genus MORDWILKOJA Del Guercio.

Plate XI, A-G.

1909. *Mordwilkoja* Del Guercio, Rivista Patol. Veget., v. 4, p. 11.

This genus was erected in 1909 for the peculiar species *Byrsocrypta vagabunda* Walsh. This differs in the antennae quite remarkably from all of the other species belonging to this tribe. The difference is in the long unguis of the sixth segment. However, the other characters and the four-segmented nature of the antennae of the stem mother seem to place it with little doubt in the Pemphigini.

There has been some doubt cast by Oestlund on the determination of Walsh's species and this has led Cockerell to propose the name *oestlundi* for the species now known so well, but, as Gillette has pointed out, Walsh evidently accepted the insect of Riley and Monell as the same species as his *vagabunda*. The insects Riley had were undoubtedly the species we know and the writer therefore accepts *vagabunda* and the generic name *Mordwilkoja*. The genus was erected with the name *vagabunda* used as type and not *oestlundi*.

Characters.—Cornicles present as somewhat elevated rings. Stem mother with four-segmented antennae, the unguis of segment VI slender and Aphis-like. Permanent sensoria ciliate. Alate form with five-segmented antennae which are armed with narrow transverse sensoria. Fore wings with the media simple, hind wings with both media and cubitus present.

Forms living in galls; the stem mother and her offspring living in the same gall, the alate forms leaving the galls in spring or early summer. Sexes unknown, but no doubt small, apterous, and beakless.

Type (monotypical). *Byrsocrypta vagabunda* Walsh.

Genus *PACHYPAPPELLA*, n. n.

Plate XI, H-M.

1909. *Pachypappa* Tullgren, Arkiv för Zoologi, Bd. 5, no. 14, p. 69.

In 1854 the genus *Pachypappa* was erected by Koch with *marsupialis* and *vesicalis* in the genus. A study of *marsupialis* shows that this species is in reality a *Pemphigus* as it shows all the characters of this genus. Tullgren, 1909, noted this and therefore interpreted the genus differently. *Marsupialis* had, however, been set as the type of the genus. *Pachypappa* Koch, therefore, becomes a synonym of *Pemphigus*, and *Pachypappa* Tullgren must receive a new name for which *Pachypappella* is here given.

Characters.—Stem mother without cornicles but with wax plates; antennæ five-segmented. Alate form with cornicles; antennæ six-segmented and with transverse sensoria. Fore wings with media once branched, hind wings with both media and cubitus present.

Type (present designation), *Pachypappa lactea* Tullgren.

Genus *PEMPHIGUS* Hartig.

Plate XI, N-U.

- 1837. *Pemphigus* Hartig, Jahresb. u. d. Fortschr. d. Forstwiss. und forstl. Naturk., v. 1, p. 645.
- 1839. *Byrsocrypta* Haliday, Ann. Nat. Hist., v. 2, p. 190.
- 1840. *Brysocrypta* Westwood, Int. Mod. Class. Ins., Synopsis, v. 2, p. 118.
- 1847. *Aphoides* Rondani, Nuovi Annali Sci. Nat. Bologna (2), v. 8, p. 439.
- 1857. *Amycla* Koch, Die Pflanz. Aphiden, p. 301.
- 1857. *Pachypappa* Koch, Die Pflanz. Aphiden, p. 263.
- 1857. *Rhizomaria* Hartig, Verhandl. d. Hils-Solling-Forstvereins, Jahrg. 1856, p. 52.
- 1859. *Tychea* Koch, Die Pflanzenläuse Aphiden, p. 296.
- 1885. *Kessleria* Lichtenstein, Mon. Puceron du Peupl., p. 16.
- 1904. *Hamadryaphis* Kirkaldy, The Entomologist, v. 37, p. 279.

In 1837 Hartig erected his genus *Pemphigus*, although it was not until 1841 that his reference to the genus as generally cited appeared. Passerini in 1860 set *bursarius* as type. In 1839 Haliday used the generic term *Byrsocrypta* but mentioned no species. In 1840 Westwood referred to this genus as *Brysocrypta* and gave *bursaria* L. as type. In 1859 Koch erected the genus *Tychea* with *graminis* Koch as type (monotypical). Schouteden (1906) has described the winged form of *Tychea graminis* Koch and stated that it is a typical *Byrsocrypta*. The writer has had no opportunity to study specimens but on the strength of this statement of Schouteden places *Tychea* as a synonym of *Pemphigus*. It is worthy of note, however, that Schouteden did not mention the cornicles, and this is a point of considerable difference if *graminis* is a *Pemphigus* or if it belongs to the *Fordini*.

In 1857 Hartig described the genus *Rhizomaria* with *priceae* Hartig as type. This species, however, appears to be a typical *Pemphigus* and *Rhizomaria* will become a synonym.

In 1857 Koch erected the genus *Amycla* and of this genus *fuscifrons* Koch has been made the type. The writer has been unable to obtain specimens of this species but from the descriptions it seems almost

certain that this species is a true Pemphigus. This will thus make the genus *Amycla* a synonym.

In 1847 Rondani described the genus *Aphioides* of which *bursaria* Fab. was indicated as the type and *Aphioides*, therefore, is a synonym.

In 1854 Koch erected the genus *Pachypappa* of which *marsupialis* Koch has been made the type. *Marsupialis*, however, is a typical Pemphigus. *Pachypappa* Koch, therefore, must become a synonym. Tullgren (1909) used *Pachypappa* in a different sense, but this is discussed under the genus *Pachypappella*.

In 1886 Lichtenstein erected the genus *Kessleria* for *spirothica* and this name was replaced by *Hamadryaphis* Kirk. in 1904. A study of this species, however, shows that it is a typical Pemphigus. Therefore, these two names will become synonyms.

Characters.—Cornicles present; wax plates, if present, weakly developed; stem-mother with four-segmented antennæ; alate form with six-segmented antennæ which are armed with narrow, oval or somewhat irregular sensoria. Fore wings with the media simple; hind wings with both media and cubitus present. Sexes small, apterous, and beakless. Oviparous female developing only one egg.

Forms living in galls, the stem-mother and her offspring in the same gall, the alate forms typically leaving the galls in the spring.

Type (fixed by Passerini, 1860), *Aphis bursaria* L.

Genus PHLOEOMYZUS Horvath.

Plate XI, W-BB.

1886. *Löwia* Lichtenstein, Mon. Puceron Peupl., p. 37.

1896. *Phloeomyzus* Horvath, Wien. Ent. Zeit., v. 15, p. 5.

In 1886 Lichtenstein erected the genus *Löwia* with *Schizoneura passerinii* Sig. as type but as this name had been used previously it was replaced in 1896 by *Phloeomyzus* Horvath.

It is with some hesitation that the writer places this genus in the Pemphigini. In some respects it suggests the Melaphini, while in many respects it strongly suggests the Thelaxini or even the Phyllaphidina. Indeed, to the Melaphini it shows striking resemblances. Without a study of the sexual forms it will be very difficult to place the genus definitely. All that can be done at the present time is to place it tentatively with the forms with which it appears to be related, and if further study shows this to be incorrect the genus can be placed definitely with its allies.

Characters.—Cornicles present, very slightly elevated. Apterous form with six-segmented antennæ. Alate form with six-segmented antennæ which are rather slender and without secondary sensoria. Fore wings with the media once branched, hind wings with both media and cubitus present. Large wax plates present on the abdomen. Wings held flat in repose.

Forms living free upon the bark of trees in colonies.

Type (monotypical), *Schizoneura passerinii* Sig.

Study based on specimens received from Mordwilko from Warsaw, Poland, and notes by Pergande on type specimens loaned by Horvath.

Genus RHIZOCTONUS Mokrzecky.

1895. *Rhizoctonus* Mokrzecky, Horae. Soc. Ent. Ross., v. 30, p. 438.

The genus *Rhizoctonus* was erected for *ampelinus* Mok., a species occurring on the vine. Through the kindness of H. F. Wilson the writer has been able to examine a slide containing alate forms. These, however, are in a very poor condition and it is impossible to determine whether or not cornicles are present. The antennæ too are much distorted. This slide seems to indicate, however, that *ampelinus* is somewhat related to *passerini* Sig., an hypothesis which is strengthened by the fact that both species hold the wings flat in repose. The genus, therefore, is placed here with some hesitation.

Characters.—Antennæ of six segments, without secondary sensoria and rather thick. Fore wings with the media simple. Hind wings with both media and cubitus present. Wings held flat in repose. Cauda and anal plate rounded.

Type (monotypical), *Rhizoctonus ampelinus* Mok.

Tribe MELAPHINI.

The tribe Melaphini is suggestive both of the Pemphigini and of the Eriosomatini. It is, however, quite distinct from both. The habits more nearly resemble those of the Pemphigini. The tribe is placed here but a study of the sexes may show that it really belongs to the Hormaphidinae. The typical host group is *Rhus*, and the galls are typically fall galls.

Characters.—Gall-inhabiting forms. Cornicles absent; antennæ of the alate form of five or six segments armed with somewhat oval or linear transverse sensoria. Sexual forms not known.

The genera may be separated as follows:

KEY TO THE GENERA OF THE MELAPHINI.

- | | |
|---|--------------|
| 1. Both media and cubitus present in the hind wings | 2. |
| Only the media present in the hind wings | Aploneura. |
| 2. Stigma of four wings pointed on distal portion and extending some distance | |
| Stigma stopping abruptly on distal extremity | Melaphis. |
| 3. Antennæ of five segments | Nurudea. |
| Antennæ of six segments | Pemphigella. |

Genus APLONEURA.

Plate XII, A-E.

1863. *Aploneura* Passerini, Aphididae Italicæ, p. 78.

1869. *Tetraneura* Derbès, Ann. des Sc. Nat. Zool. (5), v. 11, p. 106.

1848. *Baizongia* Rondani, Nuovi Annali delle Scienze Naturali, v. 9, p. 35.

The genus is distinguished quite easily from related ones by the venation of the hind wings, the relation of the cubitus and anal of the fore wings, and by the structure of the antennæ. The positive determination of the insect of Fabricius may cause *Aploneura* to fall for Rondani's name.

Characters.—Cornicles absent. Stem-mother with five-segmented antennæ; alate form with the media simple, the cubitus and anal joined near their bases. Hind wings with only the media present, antennæ of six segments, armed with large subcircular or elongate sensoria. Forms living in true galls.

Type (monotypical), *Tetraneura lentici* Pass.

Genus MELAPHIS Walsh.

Plate XII, F-K.

1866. *Melaphis* Walsh, Proc. Ent. Soc. Phila., v. 6, p. 281.

1883. *Schlechtendalia* Lichtenstein, Stett. Ent. Zeit., v. 44, p. 240.

1905. *Abamalekia* Del Guercio, Redia, v. 3, p. 364.

Walsh erected his genus for *rhois* Fitch, a species forming galls on sumach and in his discussion mentioned the Chinese gall, wondering if it could be congeneric. The writer has recently published an account of the Chinese gall¹ and therein placed *Schlechtendalia* Licht. as a synonym of *Melaphis*. Del Guercio's genus was erected with his *lazarewi* as type and placed as a thelaxine. Although the writer has never obtained specimens of this species he is of the opinion that it can not possibly be one of these insects and that it evidently belongs in the Melaphini where the shape of the stigma would immediately place it as a *Melaphis*.

Characters.—Cornicles absent. Apterous form with five-segmented antennæ. Alate form with either five or six segmented antennæ which are armed with somewhat linear or oval sensoria. Fore wings with the media simple, although sometimes slightly forked, distal extremity of the stigma rather long drawn out; hind wings with both media and cubitus present; abdomen with distinct wax plates. Forms living in galls from which the alate forms escape in late summer or fall.

Type (monotypical), *Byrsocrypta rhois* Fitch.

Genus NURUDEA Matsumura.

Plate XII, L-Q.

1917. *Nurudea* Matsumura, Synopsis of the Pemphigidae of Japan, p. 65.

1917. *Nurudeopsis* Matsumura, Synopsis of the Pemphigidae of Japan, p. 67.

1917. *Fushia* Matsumura, Synopsis of the Pemphigidae of Japan, p. 70.

Matsumura erected his genus *Nurudea* for his *Nurudea ibofushi*, a species somewhat similar to a species of *Melaphis*. This species differs quite markedly, however, in the form of the stigma. At the same time he erected the genus *Nurudeopsis* with *N. shiraii* as type. This species differs little from *ibofushi* excepting in the proportions of the segments, and in the fact that the cubitus and first anal are somewhat closer together at the base. The writer is of the opinion that these characters are not sufficient on which to form another genus. In the same work also he erected the genus *Fushia* with *Fushia rosea* Mats. as type. This species differs somewhat from the type of *Nurudea* but the writer believes that there are not differences sufficient to cause this to be considered as a separate genus. The antennæ

¹ Baker, A. C. On the Chinese gall (Aphididae—Hom.). In Ent. News, v. 28, p. 385-393, 1917.

are more slender and of somewhat different proportions and the cubitus and anal of the fore wings are united somewhat at base. In other genera, however, this difference between species is to be found, and it seems wisest not to adopt it in this group as of generic importance.

Characters.—Cornicles absent. Antennae of five segments armed with linear or somewhat oval sensoria. Fore wings with the media simple, the stigma normal; hind wings with both media and cubitus present. Sexes unknown. Forms making galls upon the leaves of plants.

Type (fixed by Matsumura, 1917), *Nurudea ibofushi* Mats.

Genus PEMPHIGELLA Tullgren.

1909. *Pemphigella* Tullgren, Arkiv för Zool., v. 5, p. 171.

1918. *Dasia* Van der Goot, Mem. Ind. Mus., v. 6, p. 152.

Characters.—Cornicles absent. Antennae of six segments armed with oval sensoria. Hind wings with both media and cubitus present. Sexes unknown. Species forming galls on plants. Type (monotypic), *Tetraneura cornicularia* Pass.

Tribe PROCIPHILINI.

The tribe Prociphilini contains forms which specialized in some directions more than did the Eriosomatini. In other ways, however, they appear to be more primitive than certain genera of that tribe. The cornicles have here disappeared altogether and large wax areas have replaced them. In their habits of gall formation, however, the Eriosomatini are more advanced than are members of the present tribe.

Characters.—Forms living in crumpled or twisted leaves or in a somewhat complete gall caused by the rolling up of the leaves of the host. Wax plates present; cornicles absent; antennae of stem mother of five segments; those of the alate form six segmented and armed with narrow, transverse, or somewhat broadly oval sensoria.

KEY TO THE GENERA OF THE PROCIPHILINI.

1. Media once forked, stem mother usually without wax plates *Asiphum*.
Media simple, stem mother with several rows of wax plates..... 2.
2. Wax plates large, those on the thorax well developed, stem mother and
offspring living together..... 3.
Wax plates not well developed, stem mother usually in a gall by herself. *Thecabius*.
3. Sensoria narrow, linear, ciliate *Prociphilus*.
Sensoria somewhat oval, nonciliate *Neoprociphilus*.

Genus ASIPHUM Koch.

Plate XII, R-X.

1857. *Asiphum* Koch, Die Pflanzenläuse Aphiden, p. 246.

1859. Type fixation, Gerstaecker, Bericht for 1857, p. 249.

1905. Type fixation, Kirkaldy, Can. Ent., v. 37, p. 418.

The genus *Asiphum* was erected by Koch with two species, *populi* Fab. and *ligustrinellum* Koch. He listed De Geer's work in the literature under *populi* Fab. The *populi* of Fabricius proves to be the *tremulae* of De Geer. Only the species *ligustrinellum* was placed

in the genus by Lichtenstein (1885) and this species has been indicated as type of the genus by Kirkaldy (1905). *Tremulae* De Geer is a well-known species but the writer has been unable to obtain *ligustrinellum* and, in fact, has been unable to learn anything definite in regard to the species. The following conception of the genus, therefore, is based upon *tremulae* De Geer in view of the fact that *ligustrinellum* appears to be unknown, and since *Aphis populi* Fab. was indicated by Gerstaecker in 1859.

Characters.—Cornicles absent; wax plates present in the alate forms; stem mother with five-segmented antennae. Alate form with six-segmented antennae which are armed with rather narrow transverse sensoria. Fore wings with the media once forked, hind wings with both media and cubitus present. Forms living in the somewhat crumpled leaves of their host.

Type (fixed by Gerstaecker, 1859), *Aphis populi* Fab.

Genus NEOPROCIPHILUS Patch.

Plate XIII, A-F.

1912. *Neoprociphilus* Patch, Bul. Me. Agr. Expt. Sta., no. 202, p. 174.

The genus *Neoprociphilus* Patch is very close indeed to *Prociphilus*, the characters which separate it being the somewhat more oval or rounded sensoria and the fact that the sensoria are not ciliate. However, in some of the species of *Prociphilus*, particularly in the fall forms, somewhat oval sensoria are met with. It is retained doubtfully.

Characters.—Stem mother with five-segmented antennae. Cornicles absent, large wax plates similar to those of *Prociphilus* present. Alate form with six-segmented antennae which are armed with oval or subcircular nonciliate sensoria. Fore wings with the media simple, hind wings with both media and cubitus present. Sexes small, apterous, and beakless. Oviparous female developing only one egg.

Forms living free upon their host, the stem mother and following generations in company.

Type (monotypical), *Pemphigus attenuatus* O. S.

Genus PROCIPHILUS Koch.

Plate XIII, G-N.

1857. *Prociphilus* Koch, Die Pflanzenläuse, p. 279.

1857. *Stagonia* Koch, Die Pflanzenläuse, p. 284.

1875. *Holzneria* Lichtenstein, Bul. Soc. Ent. Fr. (5) v. 5, p. LXXVI.

1917. *Nishiyana* Matsumura, Synopsis of the Pemphigidae of Japan, p. 90.

In 1857 Koch erected his genus *Prociphilus* with three species: *bumeliae* Schrank, *erraticus* Koch, and *gnaphalii* Kalt. Later in the work (p. 284) he used *xylostei* De Geer as the type of the genus *Stagonia*. This species, *xylostei*, is in all respects similar to *bumeliae* and therefore *Stagonia* becomes a synonym of *Prociphilus*. In 1875 Lichtenstein erected the genus *Holzneria* with *poschingeri* Holzner as type. *Poschingeri* has been considered by many authors as the alternate form of *bumeliae*. In such case *Holzneria* must necessarily

be a synonym of *Prociphilus*. Should *poschingeri*, however, be proven to be a distinct species it is so similar in all regards that *Holzneria* must remain a synonym.

In 1917 Matsumura erected the genus *Nishiyana* with *N. aomoriensis* Mats. as type, placing it close to *Prociphilus*. From this genus he separated it because of the absence of wax plates in the thorax and the somewhat shorter antennæ. It must be borne in mind, however, that the specimens he had were fall migrants. Fall migrants of several species of *Prociphilus* show very reduced wax plates, and in some these are absent altogether, although distinct in the spring migrants. It is believed that this genus is in reality *Prociphilus*.

Characters.—Cornicles absent, wax plates present, very large and well developed. Stem mother with five-segmented antennæ. Alate form with six-segmented antennæ armed with narrow transverse sensoria; secondary sensoria fringed. Fore wings with the media simple, hind wings with both media and cubitus present. Sexes small, apterous, and beakless. Oviparous females developing only one egg. Forms living in pseudogalls, the stem mother and her offspring together.

Type (fixed by Gerstaecker, 1859), *Aphis bumeliae* Schr.

Genus *THECABIUS* Koch.

Plate XIII, O-U.

1857. *Thecabius* Koch, Die Pflanzenläuse, p. 294.

1886. *Bucktonia* Lichtenstein, Monogr. d. pucerons, p. 16.

The genus *Thecabius* was erected by Koch in 1857 for his species *populneus*. This species proves to be a synonym of *Pemphigus affinis* Kalt. In 1886 Lichtenstein erected the genus *Bucktonia* with *affinis* Kalt. as type. *Bucktonia*, therefore, becomes a synonym.

Characters.—Cornicles absent; wax plates present but not prominently developed as in *Prociphilus*. Stem mother with five-segmented antennæ and rather narrow sensoria, secondary sensoria not fringed; fore wings with media simple, hind wings with both media and cubitus present. Sexual forms small, apterous, and beakless, oviparous female developing only one egg.

Forms living in galls, the stem mother usually living in a gall by herself.

Type (monotypical), *Thecabius populneus* Koch (= *Pemphigus affinis* Kalt.)

This genus is closely related to *Prociphilus* and it is with some hesitation that the writer places it as distinct. Certain species, such as *patchii* Gillette, which are undoubtedly congeneric with *affinis*, do not show the typical life habit of the stem mother living in a gall alone. However, the character of the sensoria and the undeveloped nature of the wax glands may serve to distinguish the genus.

Tribe FORDINI.

Members of the Fordini are specialized subterranean forms mostly living in the nests of ants. The aphids excrete honeydew, in return for which they are tended carefully by these insects. The apterous

forms generally are of a yellowish or brownish-yellow color, sometimes a milk white. Wax-secreting plates are present but they are not developed to the same extent as are those of the Prociphilini. The cornicles are lost entirely and the region where these usually occur is occupied by wax plates. In some species the wax areas are reduced. Some species are armed with fine hairs, whereas others are almost entirely smooth. The eyes in the apterous forms are composed of three facets. The alate forms have rather short, thick antennæ with somewhat oval sensoria. Three genera compose the tribe and these may be separated as follows:

KEY TO THE GENERA OF THE FORDINI.

1. Antennæ of the alate form composed of five segments.....Forda.
 Antennæ of the alate form composed of six segments.....2.
2. Sensoria of the antennæ of the alate form small and scattered over most of the segment, a central triangular wax plate on the thorax; apterous form with six-segmented antennæ.....Paracletus.
 Sensoria of the antennæ of the alate form larger and more evenly placed; the sensoria sometimes extending evenly across the segment. Apterous form with five-segmented antennæ, sometimes with six segments present.....Geoica.

Genus FORDA Heyden

Plate XIII, V-AA.

1837. *Forda* Heyden, Mus. Sinkbg., v. 2, p. 291.
 1841. *Rhizoterus* Hartig, Zeit. Ent., v. 3, p. 363.
 1849. *Smynthuroides* Westwood, Gardener's Chron., p. 420.
 1896. *Pentaphis* Horvath, Wien. Ent. Zeit., v. 15, p. 2.
 1909. *Pentaphis* Del Guercio, Rivist. Patol. Vegetale, n. s., v. 3, p. 332.
 1914. *Rectinasus* Theobald, The Entomologist, v. 47, p. 28.

In 1837 Heyden erected his genus *Forda*, the type of which is *formicaria* Heyden. In 1896 Horvath erected his genus *Pentaphis* with *marginata* Koch as a type, while Del Guercio in 1909 used *trivialis* Pass. as the type of a genus of the same name. Specimens of *marginata* Koch from Horvath prove that this species in every respect is similar to the type of the genus. *Pentaphis*, therefore, will become a synonym of *Forda*. Likewise specimens of *trivialis* show that this species belongs in the same genus. In 1841 Hartig erected the genus *Rhizoterus*, the type of which is *vacca*. According to Lichtenstein this species is a synonym of *formicaria* Heyden, and *Rhizoterus* also, then, becomes a synonym.

In 1914 Theobald erected his genus *Rectinasus* with his *buxtoni* as type. He based his genus on the proportions of the antennal segments, their length, and the length of the beak. The writer is opposed to basing genera on the proportions of the antennal segments, for in species in which these are of different proportions a very close relationship is evident. This is also true of the beak. Many American species taken in ants' nests and as yet undescribed have beaks ranging from small to longer than the body, but they are all evidently

closely related. The other characters mentioned by Theobald are seen to be present in the type species. The tubercles he figures and describes are the same and the spines on the first and second antennal segments are evidently the thickened, pointed, chitinized articulations of the segments common in insects of this type. We believe, therefore, that *Rectinasus* should be carried as a synonym of *Forda*. Westwood's genus was erected on his *betæ* which appears to belong here as recently indicated by the writer.

Characters.—Cornicles wanting; apterous forms with five-segmented antennæ and eyes of three facets. Alate form with five-segmented antennæ and medium-sized oval, or more or less irregularly shaped sensoria. Fore wings with media simple; hind wings with both media and cubitus present, arising slightly apart. Subterranean forms living usually in the nests of ants and tended by them.

Type (monotypical), *Forda formicaria* Heyden.

Genus **GEOICA** Hart.

Plate XIV, A-K.

- 1894. *Geoica* Hart, 18th Rept. State Ent. Ill., p. 101.
- 1890. *Tychea* Passerini, Gli Afidi, p. 30.
- 1906. *Tycheoides* Schouteden, Mem. Soc. Ent. Belg., v. 12, p. 194.
- 1906. *Kaltenbachella* Schouteden, Mem. Soc. Ent. Belg., v. 12, p. 194.
- 1909. *Trifidaphis* Del Guercio, Rivista Patol. Vegetale, n. s., v. 3, p. 332.
- 1912. *Tullgrenia* V. d. Goot, Tijdschr. voor Ent., v. 15, p. 96.
- 1913. *Trinacriella* Del Guercio, Redia, v. 9, p. 169.
- 1916. *Serrataphis* V. d. Goot, Zur Kenntniss der Blattläuse Java's, p. 263.

In 1860 Passerini used the generic name *Tychea* of Koch and placed as the typical species *phaseoli* Pass. In 1863 he used the name again, listing several species but not the species included by Koch. Therefore his interpretation of the genus can not be correct. In 1894 Hart erected his genus *Geoica* with *squamosa* as type. In 1906 Schouteden noticed Passerini's mistake and suggested the name *Tycheoides* but made *eragrostidis* Pass. the type. In the same year he erected *Kaltenbachella* with *menthae* Schout. as type. In the year 1909 Del Guercio erected *Trifidaphis* with *radicicola* Essig as type. In 1912 Van der Goot noted Passerini's mistake and proposed the name *Tullgrenia* for the *Tychea* of Passerini. In 1916 Van der Goot erected the genus *Serrataphis* with *lucifuga* Zehntner as type.

In studying cotypes and other specimens of *squamosa* certain generic characters are evident. The species is subterranean. It has five-segmented antennæ in the apterous form and six-segmented ones in the alate. It is true, however, that the apterous form sometimes has only four segments in the antennæ and the alate five. Indeed, in some alate forms there is a five-segmented antenna on one side and a six-segmented one on the other. One of these five-segmented antennæ was figured by Hart. One wing vein only was figured in the hind wing by Hart, but a very close examination shows that both the media and cubitus, though faint, are present. These are very difficult to trace in balsam mounts. In giving his name

Tycheoides Schouteden makes plain that he is naming the Tychea of Passerini and yet he sets a different type. He further states: "Le genre *Tychea* est vraisemblablement destiné à disparaître, ses espèces appartenant en réalité à *Tetraneura* ou *Byrsocrypta*." He evidently is speaking here of the Tychea of Koch, since specimens of *Tychea* Pass. do not possess the cornicles of either of the two genera mentioned.

In describing *Kaltenbachielli* Schouteden gives as a character the four-segmented antennæ, etc., of the apterous form. The alate form he did not know, but from his description of the pupa it evidently would possess six-segmented antennæ. There seems little doubt that this is another such case as *squamosa* where the apterous form has often four-segmented antennæ, although five is the normal number, the alate form normally having six. Hart's description has led Schouteden astray and he places *Geoica* close to *Forda*, separating it therefrom by the venation of the hind wing. Considering all of these facts there seems little doubt that *Kaltenbachielli* should be placed as a synonym of *Geoica*.

Specimens of *phaseoli* show very similar characters in every respect. It is true that the antennæ are somewhat longer and the hairs simple, but in every respect of importance the insects agree. The apterous form has five-segmented antennæ and the alate form has six-segmented ones with the sensoria very similar in nature. The cauda also is very similar. It is evident then that *Tychea* Pass. and *Tullgrenia* V. d. Goot become synonyms of *Geoica* Hart. Specimens of *lucifuga* Zehntner show a remarkable resemblance to *squamosa* with the exception, of course, of the squainæ. The apterous form has five-segmented and the alate form six-segmented antennæ. In general form and structure of the caudal extremity the insects are the same and, therefore, *Serrataphis* V. d. Goot will become a synonym of *Geoica*. There remains, then, to discuss the genus *Trifidaphis* Del Guercio. The cotypes of the type species show a close resemblance to the general type of *squamosa*. The apterous forms have five-segmented antennæ and in the alate form, as in *squamosa*, some forms have five segments and some forms have six. The general resemblance in other respects seems to prove that *Trifidaphis* is a synonym of *Geoica*.

It should be pointed out that the sexes described by Hart are in all probability not sexual forms, but immature specimens.

In 1913 Del Guercio erected the genus *Trinacriella* for his new species *magnifica*. He gave a brief description stating that the apterous forms had five-segmented antennæ and the alate forms six. No specimens of this species are available to the writer, but there seems little doubt that *Trinacriella* will become a synonym of *Geoica*.

Characters.—Cornicles wanting; apterous form usually with five-segmented antennæ and eyes of three facets. With the intermediate forms more facets may occur. Alate form with usually six-segmented antennæ and rather large oval sensoria with distinct rims. Fore wings with media simple. Hind wings with both media and cubitus present, though these may be faint and almost obscured in balsam. Cauda large and somewhat rectangular or rounded. Subterranean forms living on the roots of plants. Sexes small, apterous, and beakless.

Type (monotypical), *Geocis squamosa* Hart.

Genus **PARACLETUS** Heyden.

Plate XIV, L-S.

1837. *Paracletus* Heyden, Mus. Sinkbg., v. 2, p. 295.

The genus *Paracletus* is closely related to *Forda* Heyden from which it may be distinguished by the number of antennal segments in both alate and apterous forms. As with other genera of this tribe the eyes of the apterous form consist of three facets. Intermediate forms often occur, however, in which the intermediate nature is indicated only by the eyes which have the beginnings of compound eyes, such as are found in the alate form. There never are, however, complete compound eyes. The genus was erected by Heyden in 1837. The species live in close association with ants.

Characters.—Cornicles absent. Apterous form with six-segmented antennæ and eyes of three facets; alate form with six-segmented antennæ which possess many rather small, oval sensoria. Fore wings with media simple, hind wings with both media and cubitus present, arising some distance apart. Thorax with a central wax plate. Forms living in the nest of ants and cared for by them. Sexes small, apterous, and beakless. In some cases only one claw is met with on the foot, while in other cases the normal number of two is present. This appears to be no definite character, as sometimes a claw is dropped from one foot and sometimes from another.

Type (monotypical), *Paracletus cimiciformis* Heyden.

Subfamily IV, HORMAPHIDINAE.

The genera placed in this subfamily have usually been placed with the Eriosomatinae, or Pemphiginae, as it has been sometimes called. Mordwilko, however, placed these forms as his third tribe under the subfamily Aphidinae next to his tribe Callipterea. Something can be said in favor of both of these placings. In the first instance, the species in general form, antennal structure, and habit of gall formation are no doubt suggestive of the Eriosomatinae. On the other hand, their structure in regard to cauda and anal plate is very like the Callipterina and the sexual forms appear to have a development of their own, although they are nearer in many ways to the Aphidinae than to the Eriosomatinae.

It is the author's belief that these forms should constitute a separate subfamily. It has developed the habit of gall formation and the sensory characters which usually accompany it, while at the same time it has retained in the sexual female the normal develop-

ment of the ovaries found in the more primitive groups, and has retained in both sexual forms the beak and the ability to feed. This at once suggests a different line of development from that taken by the Eriosomatinae, although in some of its habits the Hormaphidinae agrees with that subfamily. In other lines, however, marked differences are met with here and one of the most striking of these is development of aleyrodiform generations, which remain stationary upon the host. Such a development is never met with in the Eriosomatinae, although the sexual forms are much more specialized.

Since many of the genera of the Hormaphidinae are gall formers, sensoria very similar to those met with in the Eriosomatinae are met with here also. Indeed the same annular sensoria found in the Eriosomatini are even more pronounced in the Hormaphidinae and the sensoria on the wing bases are prominent and often, numerous.

The cornicles in the present subfamily are sometimes absent or, as is usually the case, reduced to mere rings. In some genera, however, they may be elevated slightly on broad shallow cones, somewhat suggestive of those of Anoecia. No prominent cornicles, however, occur.

In the wing venation there is often a considerable reduction and this shows also the specialized nature of the insects. The venation is comparable to that met with in the Eriosomatinae. In the fore wings the media is either simple or once branched, the radial sector, cubitus, and anal are present, but the cubitus and anal are often fused near their bases. In the hind wings both the media and cubitus are sometimes present, but often only the media remains.

Great specialization in wax-producing organs occurs. In many of the forms these agree with the ones found in the Pemphigini. In certain aleyrodiform generations and in some sexual forms agglomerate glands or rather groups of small glands are seen. These may be arranged in different ways and often are placed about the margin of the insect so that it possesses a distinct lateral fringe, very like that of an aleyrodid. In fact some of these insects on this account are very often mistaken for aleyrodids.

The sexual forms are often quite small and possess large wax-producing areas. Others may lack these. All, however, develop to normal adults.

The habit of gall formation is very marked here. Indeed, some species form galls on two different species of plants, migrating between the two.

Characters.—Aerial forms living in galls or sometimes free upon the host. The mesothorax in many forms altered so that its divisions are more or less unobservable, the entire mesothorax often showing as only one plate. Scalelike or aleyrodiform

generations often developed. Cornicles often reduced to mere ringlike openings or entirely absent. Sexual forms small and apterous but with fully developed beaks. Oviparous female laying several eggs.

KEY TO THE TRIBES OF THE HORMAPHIDINAE.

1. Aleyrodiform generations developed..... 2.
 Aleyrodiform generations not developed..... OREGMINI.
2. Cornicles absent; insects usually gall formers..... HORMAPHIDINI.
 Cornicles usually present; insects usually not gall formers..... CERATAPHIDINI.

Tribe HORMAPHIDINI.

Members of this tribe are distinguished easily from those of other tribes in that the cornicles are absent and aleyrodiform generations are developed. These remain more or less quiescent upon the foliage. Some different forms of the species are often gall producers. All secrete wax from special pores. Considerable variation is met with in the development of the aleyrodiform generations. Sensoria of the alate forms are usually narrow and annular.

Only two genera are so far recorded.

KEY TO THE GENERA OF THE HORMAPHIDINI.

- Antennæ of the alate forms composed of three segments, hind wings with only the media present Hormaphis.
 Antennæ of the alate forms composed of five segments, hind wings with both media and cubitus present..... Hamamelistes.

Genus HAMAMELISTES Shimer.

Plate XIV, T-X.

1867. *Hamamelistes* Shimer, Trans. Am. Ent. Soc., v. 1, p. 284.

1896. *Tetraphis* Horvath, Wien. Ent. Zeit., v. 15, p. 6.

Shimer included two species in this genus, *spinosus* Shimer and *cornu* Shimer. The latter species, as suspected by him, is a synonym of *hamamelidis* Fitch. This species has been made the type of *Hormaphis*.

Characters.—Cornicles absent. Stem mother with four-segmented antennæ. Aleyrodiform generations developed. Alate form with five-segmented antennæ which are armed with numerous annular sensoria. Wings held flat in repose; fore wings with the media simple; hind wings with both media and cubitus usually present; cauda knobbed, anal plate bilobed; wax-secreting areas abundantly present in the apterous forms. Sexes small and apterous but with beaks developed, oviparous female laying several eggs.

Forms living in galls upon the leaves or scale-like on the leaves or twigs.

Type (one unquestioned species), *Hamamelistes spinosus* Shimer.

Genus *HORMAPHIS* Osten-Sacken.

Plate XIV, Y-FF.

1861. *Hormaphis* Osten-Sacken, Stettiner Ent. Zeit., p. 422.

The genus *Hormaphis* was erected by Osten Sacken for a species he described as *hamamelidis*. This species it later proved was the same described by Fitch as *Byrsocrypta hamamelidis*. The genus later was made to include *spinosus* Shimer, but the distinction between this genus and the one described by Shimer has been pointed out by Pergande.¹

Characters.—Cornicles absent; aleyrodiform generations developed; wax glands very numerous; stem mother with three-segmented antennæ; alate forms with three-segmented antennæ which are armed with distinct annular sensoria. Wings held flat in repose; fore wings with the media simple; hind wings with the cubitus absent. Sexual forms small and apterous, possessing beaks, oviparous female laying several eggs.

Type (monotypical), *Hormaphis hamamelidis* O. S. (*Byrsocrypta hamamelidis* Fitch).

Tribe OREGMINI.

Characters.—Forms living in galls or otherwise upon the leaves of plants, possessing cornicles and wax secreting glands. Antennæ of the winged forms usually armed with annular sensoria; cauda rounded or somewhat knobbed, anal plate somewhat bilobed. No aleyrodiform generations developed. The sexual forms appear to be unknown.

KEY TO THE GENERA OF THE OREGMINI.

- | | |
|---|-----------------|
| 1. Vertex with two horn-like projections..... | 2. |
| Vertex without such horn-like projections..... | 3. |
| 2. Antennæ five-segmented..... | Oregma. |
| Antennæ four-segmented..... | Ceratoglyphina. |
| 3. Antennæ of apterous form with five segments..... | 4. |
| Antennæ of apterous form with four segments..... | Glyphinaphis. |
| 4. Media of fore wings once branched..... | Astegopteryx. |
| Media of fore wings simple..... | Mansakia. |

Genus *ASTEGOPTERYX* Karsch.

Plate XV, Q-X.

1890. *Astegopteryx* Karsch, Ber. deutsch Botan. Ges., v. 8, p. 52.1906. *Nipponaphis* Pergande, Ent. News, v. 17, p. 205.1916. *Schizoncuraphis* Van der Goot, Zur Kenntniss der Blattläuse Java's, p. 245.

The genus *Astegopteryx* was erected with *styracophila* Karsch as type. Another species, *nekoashi*, was described by Sasaki before the International Congress at Brussels in 1911 and a third species, *styraci*, was described by Matsumura in 1917. It is possible, therefore, to gain a fair conception of the characters. In 1906 Pergande erected his genus *Nipponaphis* with *distychii* Perg. as type. This species was stated to be from *Distylium racemosum* in Japan, on

¹ Pergande, T. The life history of two species of plant lice inhabiting both the witch-hazel and birch. U. S. Dept. Agr. Bur. Ent. Tech. Ser. no. 9. 1901.

which it forms galls. In 1916 Van der Goot erected his *Schizoneuraphis* with *gallorum* V. d. Goot as type. This species was said to form galls on *Distylium stellare*.

The genus *Astegopteryx* can be separated as far as the recognized forms are concerned by the proportion of the antennal segments and some variation in the shape of the stigma. These differences are not, however, of large importance and *Nipponaphis* should be a synonym of *Astegopteryx*. In the same way, the type of Van der Goot's genus is not sufficiently different to warrant the erection of a new genus and *Schizoneuraphis* also should be considered a synonym.

Characters.—Cornicles broad rings; apterous form with five-segmented antennæ; alate form with five-segmented antennæ which are armed with annular sensoria. fore wings with the media once branched; hind wings with both media and cubitus present. Stigmal vein arising rather far back on the stigma. Cauda rounded, anal plate somewhat bilobed; forms living in galls.

Sexual forms unknown.

Type (monotypical), *Astegopteryx styracophila* Karsch.

Genus **CERATOLYPHINA** Van der Goot.

Plate XV, M-P.

1916. *Ceratolyphina* Van der Goot, Zur Kenntniss der Blattläuse Java's, p. 237.

Characters.—Cornicles present as mere pores. Vertex with two hornlike projections. Antennæ of four segments; cauda and anal plate both rounded. Winged forms unknown.

Type (fixed by V. d. Goot, 1916), *Ceratolyphina bambusae* V. d. Goot.

Genus **GLYPHINAPHIS** Van der Goot.

Plate XV, H-K.

1916. *Glyphinaphis* Van der Goot, Zur Kenntniss der Blattläuse Java's, p. 232.

Characters.—Cornicles present as mere pores; antennæ of four segments which are armed with linear sensoria. Fore wings with the media once branched; hind wings with both media and cubitus present; cauda knobbed; anal plate rounded; body covered with stout hairs.

Type (fixed by V. d. Goot, 1916), *Glyphinaphis bambusae* V. d. Goot.

Genus **MANSAKIA** Matsumura.

Plate XV, L.

1917. *Mansakia* Matsumura, Synopsis of the Pemphigidae of Japan, p. 59.

The author of the genus *Mansakia* stated that it is closely allied to *Hormaphis*, but it would appear to the writer to be related to the genera in the Oregmini as understood in the present classification. The presence of the cornicles would indicate that the genus is not related as closely to *Hormaphis* as to *Astegopteryx*, but its host and the nature of the gall would place it close to *Hamamelistes*. Since all of the forms are not known it is impossible to state positively its position.

Characters.—Cornicles present as mere rings. Antennæ of five segments armed with annular sensoria. Fore wings with the media simple, hind wings with two oblique veins. Cauda rounded, anal plate somewhat bilobed. Sexes not known.

Forms causing galls upon plants, the galls usually armed with numerous long projections.

Type (fixed by Matsumura, 1917), *Mansakia miyabei* Mats.

• Genus OREGMA Buckton.

Plate XV, A-G.

1893. *Oregma* Buckton, Ind. Mus. Notes, v. 3, p. 87.

1897. *Ceratovacuna* Zehntner, Mededl. Proefs. Java, n. s., no. 37, p. 29.

In 1893 Buckton established his genus *Oregma* with *bambusae* Buckton as type, while in 1897 Zehntner established his *Ceratovacuna* with *lanigera* Zehntner as type. Specimens of both of these species sent by Zehntner and specimens of *bambusae* from Green taken in Ceylon show that these genera must be considered the same.

Characters.—Both alate and apterous forms with two hornlike projections on the vertex, wax gland areas present; antennæ five-segmented, those of the alate form with narrow annular sensoria; cauda rounded or somewhat knobbed; fore wings with media twice forked, hind wings with both media and cubitus present; cornicles broad, slightly elevated rings.

Type (monotypical), *Oregma bambusae* Buckt.

Tribe CERATAPHIDINI.

This tribe is closely related to the Hormaphidini but differs in that very distinct cornicles are here present. The apterous forms are scalelike and quiescent and feed upon the surfaces of the leaves. The alate forms possess annular sensoria. Wax secretion is abundant.

The genera may be separated as follows:

KEY TO THE GENERA OF THE CERATAPHIDINI.

Antennæ of the aleyrodiform generations of five segments Aleurodaphis.
Antennæ of the aleyrodiform generations of four segments Cerataphis.
Antennæ of aleyrodiform generations of three segments Thoracaphis.

Genus ALEURODAPHIS Van der Goot.

Plate XVI, A-E.

1916. *Aleurodaphis* Van der Goot, Zur Kenntniss der Blattläuse Java's, p. 239.

This genus was erected for one species occurring in Java.

Characters.—Form flat, aleyrodiform, three distinct divisions evident; cornicles present as mere rings. Margin with wax secreting glands; dorsum also with many small glands. Cauda rather elongate and knobbed, anal plate bilobed. Antennæ five-segmented; eyes of the apterous forms with three facets.

Type (fixed by Van der Goot, 1916), *Aleurodaphis blumeae* V. d. Goot.

Genus CERATAPHIS Lichtenstein.

Plate XVI, F-M.

1862. *Boisduvalia* Signoret, Ann. Ent. Soc. France (4), v. 8, p. 400.

1882. *Cerataphis* Lichtenstein, Bul. Ent. Soc. France (6), v. 2, p. xvi.

Signoret erected his genus *Boisduvalia* in connection with his aleyrodid monograph. He placed *Coccus lataniae* Bois. as type. Later, however, he considered this a coccid genus. The name was used in the Diptera in 1830, and is therefore not available. The name *Cerataphis* used by Lichtenstein in 1882 appears as the next name applied to the genus.

Characters.—Cornicles present as mere rings. Apterous form with four-segmented antennæ and aleyrodiform, with two divisions to the body; wax glands prominent; vertex with two hornlike projections; alate form with five-segmented antennæ, the segments armed with narrow annular sensoria. Fore wings with the media once branched, hind wings with both media and cubitus present. Cauda knobbed; anal plate bilobed.

Type (monotypical), *Coccus lataniae* Bois.

Genus THORACAPHIS Van der Goot

Plate XVI, N-W.

1916. *Thoracaphis* Van der Goot, Zur Kenntniss der Blattläuse Java's, p. 242.

Only the apterous form of one species of this genus has been described. Other species, however, are available for study, through the generosity of Professor Van der Goot.

Characters.—Cornicles present and quite distinct, occasionally absent, however, in the apterous form. Apterous form with three-segmented antennæ, flat and with a posterior lobe. Alate form with five-segmented antennæ armed with annular sensoria. Fore wings with the media once branched; hind wings with both media and cubitus present. Cauda somewhat knobbed, anal plate bilobed.

Type (monotypical), *Thoracaphis arboris* V. d. Goot.

GENERA NOT PLACED.

A number of genera have been described which the writer has been unable to place. These genera are discussed in the following notes.

Genus RHIZOBIUS Burmeister.

- 1835. *Rhizobius* Burmeister, Handbuch der Entomologie, p. 78.
- 1849. *Rhizophthiridum* Van der Hoeven, Handb. Dierkunde v. 1, p. 508.
- 1860. *Rhyzoicus* Passerini, Gli Afidi, p. 30.
- 1863. *Rizobius* Passerini, Aphididae Italicae, p. 79.
- 1919. *Rhizoicus* Del Guercio, Redia, v. 12, p. 251.

The genus *Rhizobius* has generally been considered as a good aphid genus and writers have referred to species in this genus as having but one claw to the tarsus. However, as indicated under *Paracletus* the writer believes this is a variable character and we have no definite knowledge in regard to *pilosellae* Burm. Buckton's species of course was not in the original genus and therefore can not be used as type nor was it in Passerini's conception of *Rhyzoicus*. After placing *Rhyzoicus* Pass. with *jujubae* Buckton as type, Del Guercio erects the genus *Neorhizobius*, distinguished by having two claws, and in which he places *graminis* Thos., *poae* Del Guercio, *stramineus* Del Guercio, and *ulmiphilus* Del Guercio.

In 1860 Passerini set *sonchi* Pass. as the type of *Rhizobius* Burm., and in a footnote suggested the name *Rhyzoicus* as a new name for *Rhizobius*, since this name had previously been used in the Coleoptera. Such procedure, however, is not allowable since *sonchi* Pass. was not in the original genus. Of the two species in the original genus *pilosellae* Burm. has been accepted as type.

Del Guercio in 1917 used the generic name *Rhizoicus* Pass., spelling it with an "i" instead of a "y", and *jujubae* Buckton as the type.

In the writer's opinion the genus *Rhizobius* must remain unknown until the type species *pilosellae* becomes known and carefully studied.

The name *Rhizophthiridum* was given to this genus to replace *Rhizobius* Burm.

Genus NEORHIZOBIUS Del Guercio.

- 1917. *Neorhizobius* Del Guercio, Redia, v. 12, p. 251.

As indicated under the discussion of *Rhizobius*, four species are placed in this genus by Del Guercio. Three species are described as new and only in the apterous forms.

Two of these forms have five-segmented antennae and one of them four-segmented ones, and when the alate forms are found they will in all probability be shown to represent species either of *Forda* or *Geoica*. The basing of genera upon the relative lengths of the antennal segments would create a very large number of genera and separate related forms. The genus *Neorhizobius*, therefore, the

writer considers composed of apterous forms, which really belong in older and well-recognized genera, but which can not be definitely placed until the alate forms have been secured and studied.

Genus *SCHOUTEDENIA* Rübsaamen.

1905. *Schoutedenia* Rübsaamen, Marcellia, v. 4, p. 19.

This genus, which was described for *ralumensis* Rüb., is here listed as unknown. The gall formed by the species is described but the writer, never having been able to obtain either gall or insect, would be able only to guess at its position from the description.

Genus *CLAVIGERUS* Szépligeti.

Clavigerus Szépligeti, Rovarászati Lapok, v. 1, p. 4.

This genus was described in the only volume issued of the *Journal* cited. The writer has been unable to secure a copy or any details of the description given.

ADDENDA.

The following generic names have been employed by Mordwilko (*Fauna Russ.* vol. 1, Aphidodea) without, apparently, the mention of any species in connection therewith. They have not been considered in the foregoing paper: *Anameson*, *Aorison*, *Chaetosiphon*, *Corylobium*, *Elatobium*, *Euaulax*, *Eurythaphis*, *Halmodaphis*, *Impatientinum*, *Jaxartaphis*, *Nasonovia*, *Orobion*, *Paczoskia*, *Sitobium*, *Staticobium*, *Tlja*, *Turanaphis*, *Uroleucon* (subgenus), *Uromelan*. The subgenera *Dactynotus* Raf., *Cladoxus* Raf., and *Adactynus* Raf., have not been considered.



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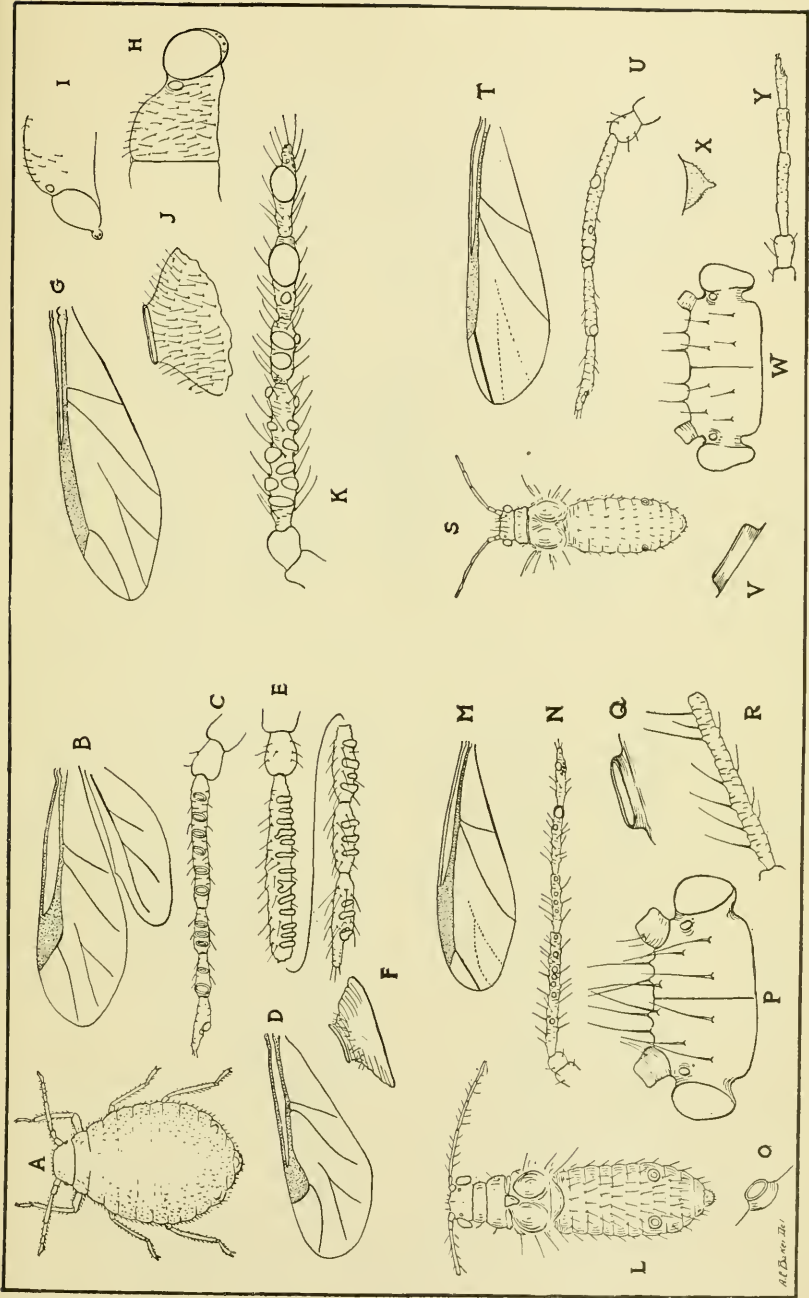
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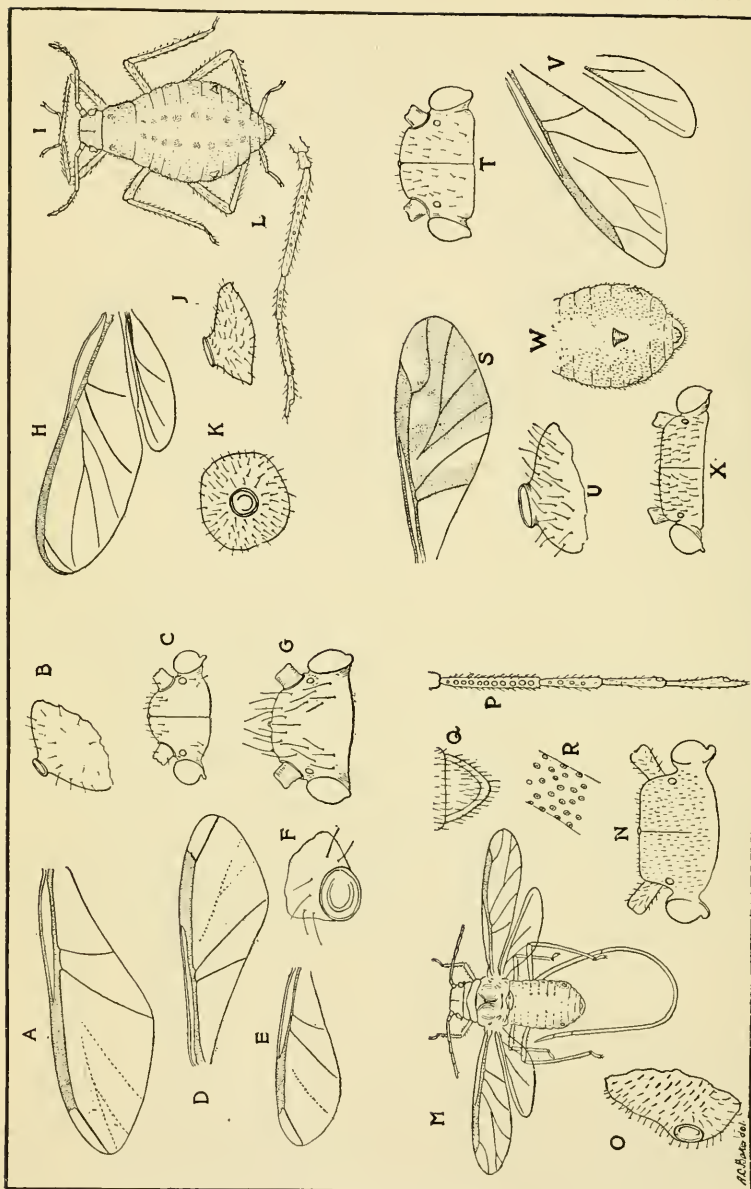
PLATE I.

- A.—*Anoecia querci*, apterous form.
- B.—*Anoecia querci*, wings.
- C.—*Anoecia querci*, antenna of alate form.
- D.—*Anoecia corni*, fore wing.
- E.—*Anoecia corni*, antenna of alate form.
- F.—*Anoecia corni*, cornicle of alate form.
- G.—*Nippolachnus pyri*, fore wing.
- H.—*Nippolachnus pyri*, head of alate form.
- I.—*Anoecia corni*, head of alate form.
- J.—*Nippolachnus pyri*, cornicle of alate form.
- K.—*Nippolachnus pyri*, antenna of alate form.
- L.—*Eulachnus agilis*, body of alate form.
- M.—*Eulachnus agilis*, fore wing.
- N.—*Eulachnus agilis*, antenna of alate form.
- O.—*Eulachnus agilis*, cornicle of alate form.
- P.—*Eulachnus rileyi*, head of alate form.
- Q.—*Eulachnus rileyi*, cornicle of alate form.
- R.—*Eulachnus rileyi*, segment III, antenna of alate form.
- S.—*Essigella californica*, body of alate form.
- T.—*Essigella californica*, fore wing.
- U.—*Essigella californica*, antenna of alate form.
- V.—*Essigella californica*, cornicle of alate form.
- W.—*Essigella californica*, head of alate form.
- X.—*Essigella californica*, cauda of alate form.
- Y.—*Essigella californica*, antenna of apterous form



GENERIC CLASSIFICATION OF APHIDIDAE.

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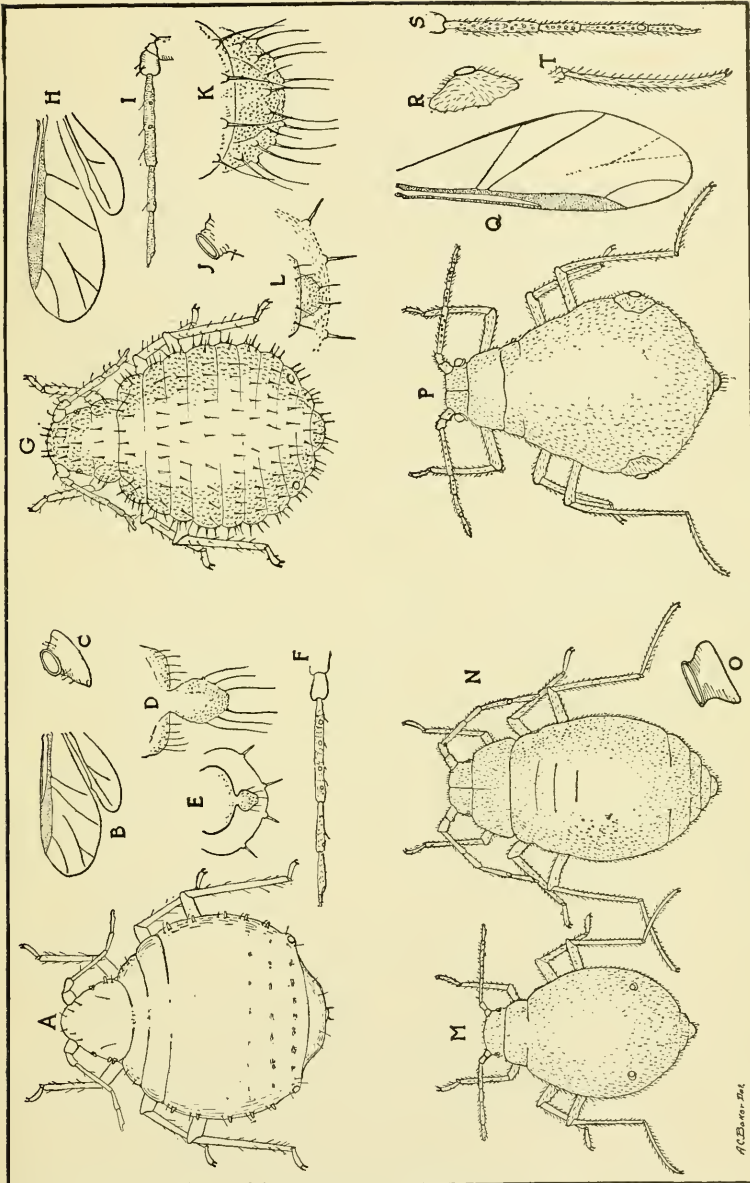
GENERIC CLASSIFICATION OF APHIDIDAE.

PLATE II.

- A.—*Dilachnus ponderosae*, fore wing.
- B.—*Dilachnus ponderosae*, cornicle of apterous form.
- C.—*Dilachnus ponderosae*, head of alate form.
- D.—*Schizolachnus tomentosus*, fore wing.
- E.—*Unilachnus parvus*, fore wing.
- F.—*Unilachnus parvus*, cornicle of alate form.
- G.—*Unilachnus parvus*, head of alate form.
- H.—*Longistigma caryae*, wings.
- I.—*Longistigma caryae*, apterous form.
- J.—*Longistigma caryae*, cornicle.
- K.—*Longistigma caryae*, cornicle.
- L.—*Longistigma caryae*, antenna of alate form.
- M.—*Stomaphis quercus*, alate form.
- N.—*Stomaphis quercus*, head of alate form.
- O.—*Stomaphis quercus*, cornicle of alate form.
- P.—*Stomaphis quercus*, antenna of alate form.
- Q.—*Stomaphis quercus*, cauda and anal plate.
- R.—*Stomaphis quercus*, pits on rostrum.
- S.—*Pterochlorus roboris*, wing.
- T.—*Pterochlorus roboris*, head of alate form.
- U.—*Pterochlorus roboris*, cornicle of alate form.
- V.—*Pterochlorus viminalis*, wings.
- W.—*Pterochlorus viminalis*, abdomen of alate form.
- X.—*Pterochlorus viminalis*, head of alate form.

PLATE III.

- A.—*Thelaxes dryophila*, apterous form.
- B.—*Thelaxes dryophila*, wings.
- C.—*Thelaxes dryophila*, cornicle of alate form.
- D.—*Thelaxes dryophila*, cauda of alate form.
- E.—*Thelaxes dryophila*, cauda of apterous form.
- F.—*Thelaxes dryophila*, antenna of alate form.
- G.—*Glyphina betulae*, apterous form.
- H.—*Glyphina betulae*, wings.
- I.—*Glyphina betulae*, antenna of alate form.
- J.—*Glyphina betulae*, cornicle of alate form.
- K.—*Glyphina betulae*, cauda and anal plate of alate form.
- L.—*Glyphina betulae*, cauda and anal plate of apterous form.
- M.—*Neotrama delguercioi*, apterous form.
- N.—*Trama troglodytes*, apterous form.
- O.—*Neotrama delguercioi*, cornicle.
- P.—*Protrama radialis*, apterous form.
- Q.—*Protrama radialis*, fore wing.
- R.—*Protrama radialis*, cornicle of alate form.
- S.—*Protrama radialis*, antenna of alate form.
- T.—*Protrama radialis*, tarsus of alate form.



GENERIC CLASSIFICATION OF APHIDIDAE.

A.C. Davis, Del.

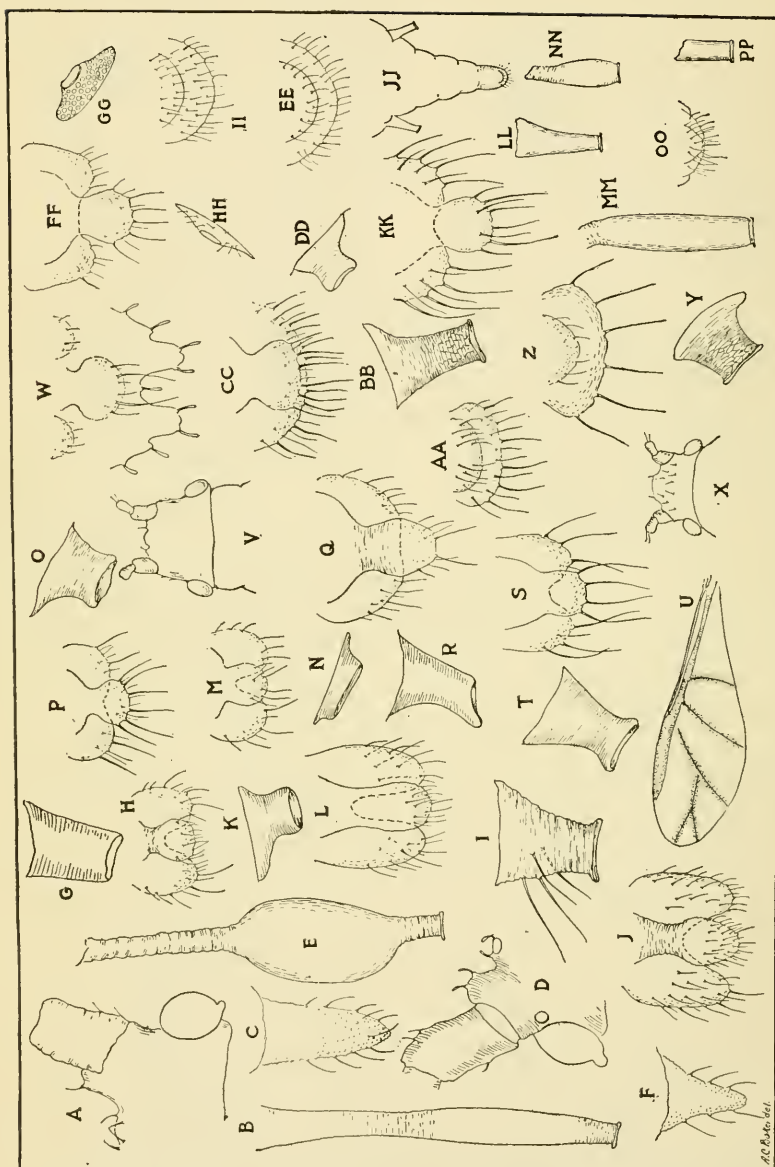
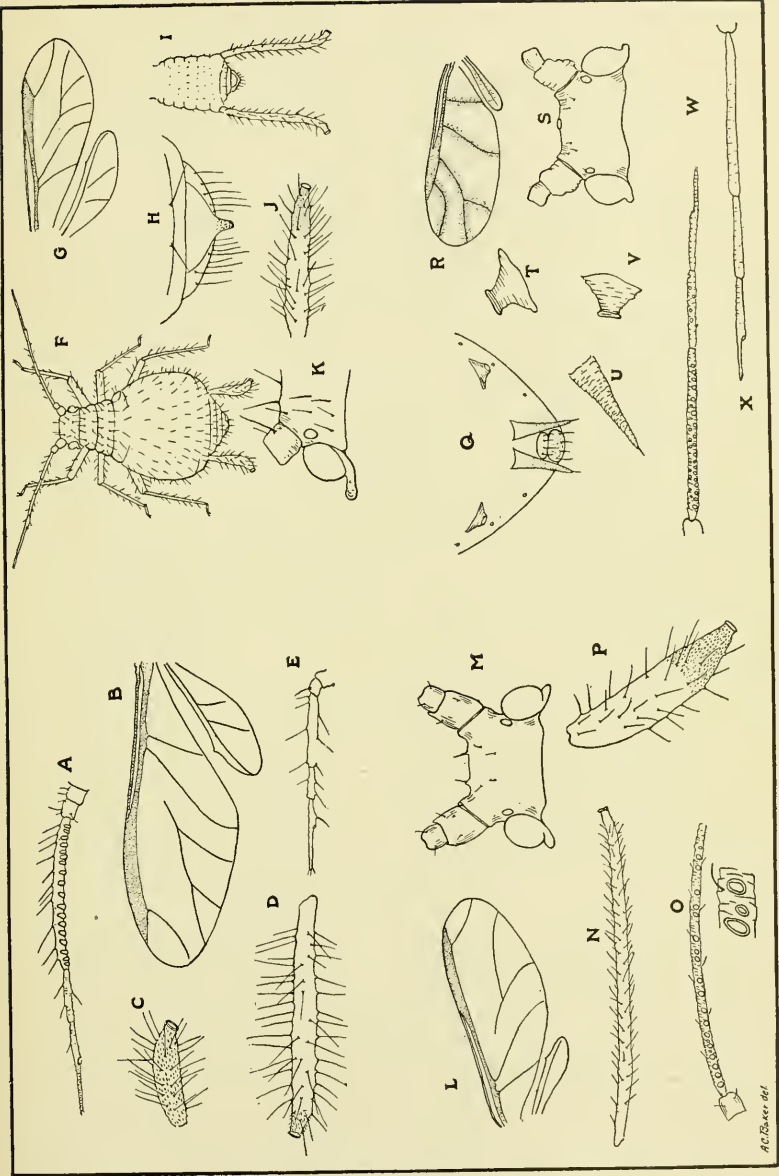


PLATE IV.

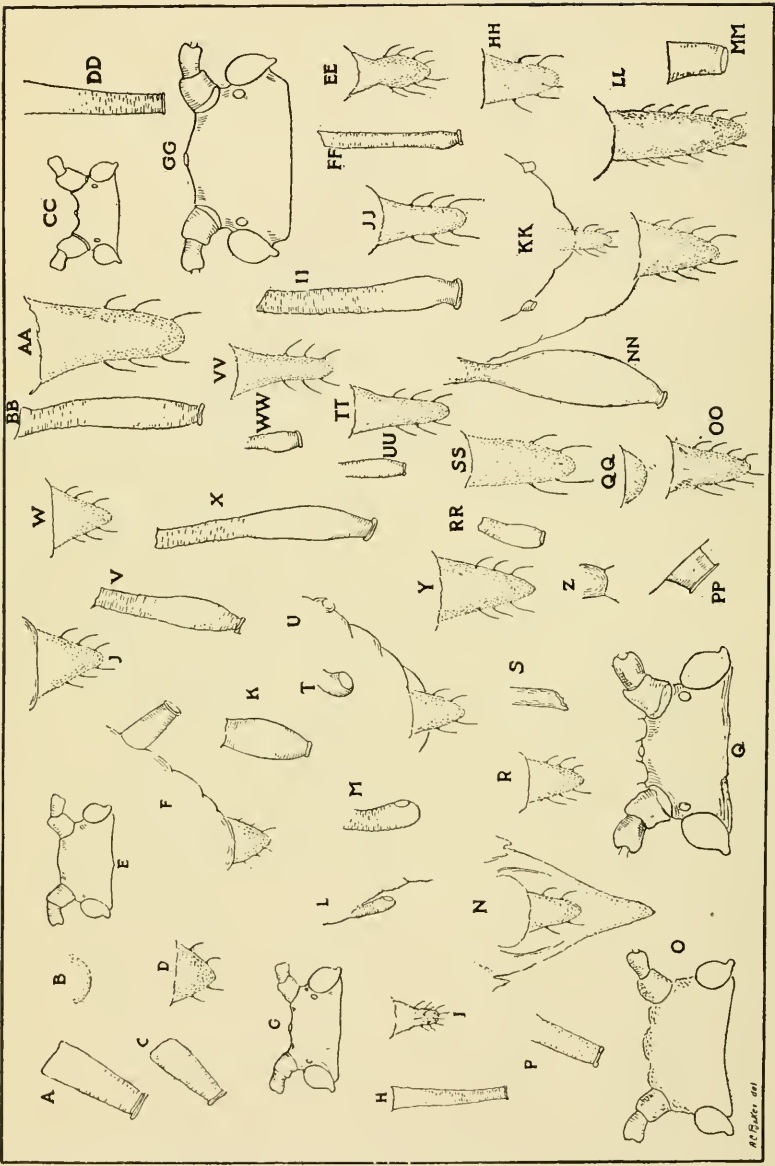
- A.—*Amphorophora rubi*, head of apterous form.
- B.—*Amphorophora rubi*, cornicle.
- C.—*Amphorophora rubi*, cauda.
- D.—*Rhopalosiphoninus latysiphon*, head of alate form.
- E.—*Rhopalosiphoninus latysiphon*, cornicle of alate form.
- F.—*Rhopalosiphoninus latysiphon*, cauda of alate form.
- G.—*Myzocallis coryli*, cornicle.
- H.—*Myzocallis coryli*, cauda and anal plate.
- I.—*Callipterus juglandis*, cornicle.
- J.—*Callipterus juglandis*, cauda and anal plate.
- K.—*Therioaphis tiliae*, cornicle.
- L.—*Therioaphis tiliae*, cauda and anal plate.
- M.—*Monellia caryella*, cauda and anal plate.
- N.—*Monellia caryella*, cornicle.
- O.—*Chromaphis juglandicola*, cornicle.
- P.—*Chromaphis juglandicola*, cauda and anal plate.
- Q.—*Euceraaphis betulae*, cauda and anal plate.
- R.—*Euceraaphis betulae*, cornicle.
- S.—*Calaphis betulella*, cauda and anal plate.
- T.—*Calaphis betulella*, cornicle.
- U.—*Calaphis betulella*, fore wing.
- V.—*Saltusaphis scirpus*, head of apterous form.
- W.—*Saltusaphis scirpus*, cauda and anal plate.
- X.—*Thripsaphis balli*, head of apterous form.
- Y.—*Neothomasia populicola*, cornicle.
- Z.—*Neothomasia populicola*, cauda and anal plate.
- AA.—*Periphyllus negundinis*, cauda and anal plate.
- BB.—*Periphyllus negundinis*, cornicle.
- CC.—*Chaitophorus populi*, cauda and anal plate.
- DD.—*Symydobius oblongus*, cornicle.
- EE.—*Symydobius oblongus*, cauda and anal plate.
- FF.—*Phyllaphis fagi*, cauda and anal plate.
- GG.—*Phyllaphis fagi*, cornicle.
- HH.—*Tamalea coweni*, cornicle.
- II.—*Tamalea coweni*, cauda and anal plate.
- JJ.—*Drepanaphis acerifolii*, oviparous abdomen.
- KK.—*Drepanaphis acerifolii*, cauda and anal plate of alate form.
- LL.—*Drepanaphis acerifolii*, cornicle.
- MM.—*Drepanosiphum platanoides*, cornicle.
- NN.—*Melanoxanthrium populifoliae*, cornicle.
- OO.—*Melanoxanthrium populifoliae*, cauda and anal plate.
- PP.—*Pterocomma populeus*, cornicle.

PLATE V.

- A.—*Eutrichosiphum pasaniae*, antenna of alate form.
- B.—*Eutrichosiphum pasaniae*, wings.
- C.—*Eutrichosiphum pasaniae*, cornicle of apterous form.
- D.—*Eutrichosiphum pasaniae*, cornicle of alate form.
- E.—*Eutrichosiphum pasaniae*, antenna of apterous form.
- F.—*Greenidea anonae*, apterous form.
- G.—*Greenidea artocarp*i, wings.
- H.—*Greenidea artocarp*i, cauda of apterous form.
- I.—*Greenidea artocarp*i, cornicle of apterous form.
- J.—*Greenidea anonae*, abdomen of alate form.
- K.—*Greenidea anonae*, head of alate form.
- L.—*Greenideoida elongata*, wings.
- M.—*Greenideoida* sp., head of alate form.
- N.—*Greenideoida* sp., cornicle of alate form.
- O.—*Greenideoida* sp., third antennal segment of alate form.)
- P.—*Greenideoida hanna*e, cornicle of apterous form.
- Q.—*Setaphis luteus*, caudal portion of apterous form.
- R.—*Setaphis luteus*, wings.
- S.—*Setaphis luteus*, head of alate form.
- T.—*Setaphis luteus*, cornicle of alate form.
- U.—*Setaphis luteus*, spine of alate form.
- V.—*Setaphis luteus*, cornicle of apterous form.
- W.—*Setaphis luteus*, antenna of alate form.
- X.—*Setaphis luteus*, antenna of apterous form.



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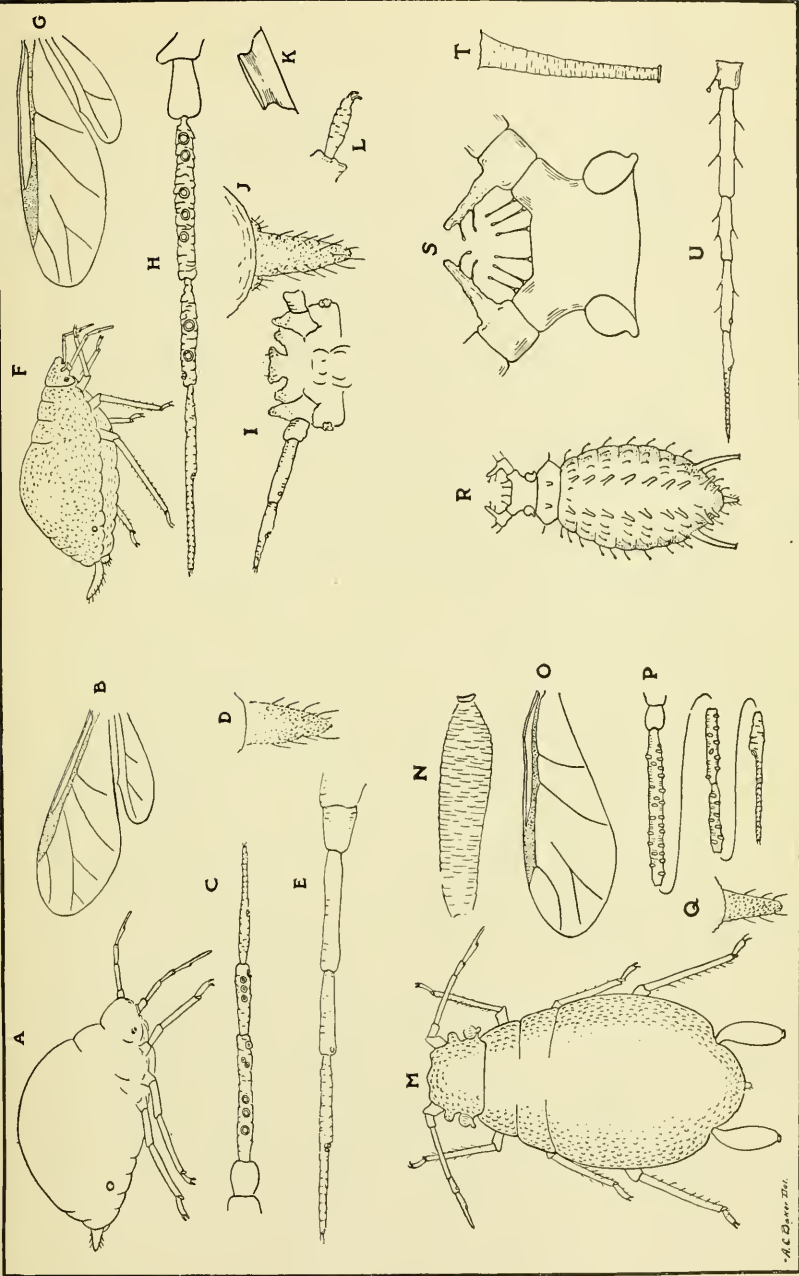
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PLATE VI.

- A.—*Acaudus lychnidis*, cornicle of alate form.
- B.—*Acaudus lychnidis*, cauda of alate form.
- C.—*Anuraphis amygdali*, cornicle of alate form.
- D.—*Anuraphis amygdali*, cauda of alate form.
- E.—*Anuraphis amygdali*, head of alate form.
- F.—*Anuraphis carotae*, cornicle and cauda of alate form.
- G.—*Aphis sambuci*, head of alate form.
- H.—*Aphis sambuci*, cornicle of alate form.
- I.—*Aphis sambuci*, cauda of alate form.
- J.—*Brevicoryne brassicae*, cauda of alate form.
- K.—*Brevicoryne brassicae*, cornicle of alate form.
- L.—*Aspidaphis polygonii*, cornicle of alate form.
- M.—*Aspidaphis polygonii*, cornicle more enlarged.
- N.—*Aspidaphis polygonii*, cauda of apterous form.
- O.—*Aspidaphis polygonii*, head of apterous form.
- P.—*Atarsos grindeliae*, cornicle of alate form.
- Q.—*Atarsos grindeliae*, head of alate form.
- R.—*Atarsos grindeliae*, cauda of alate form.
- S.—*Atarsos grindeliae*, tibia of alate form.
- T.—*Brachycolus stellariae*, cornicle of alate form.
- U.—*Brachycolus stellariae*, cauda of alate form.
- V.—*Carolinaia cyperi*, cornicle of alate form.
- W.—*Carolinaia cyperi*, cauda of alate form.
- X.—*Cavariella pastinacae*, cornicle of alate form.
- Y.—*Cavariella pastinacae*, cauda of alate form.
- Z.—*Cavariella pastinacae*, tubercle of alate form.
- AA.—*Hyadaphis xylostei*, cauda of apterous form.
- BB.—*Hyadaphis xylostei*, cornicle of apterous form.
- CC.—*Toxoptera aurantiae*, head of alate form.
- DD.—*Toxoptera aurantiae*, cornicle of alate form.
- EE.—*Toxoptera aurantiae*, cauda of alate form.
- FF.—*Rhopalosiphum rufomaculata*, cornicle of alate form.
- GG.—*Rhopalosiphum rufomaculata*, head of alate form.
- HH.—*Rhopalosiphum rufomaculata*, cauda of alate form.
- II.—*Rhopalosiphum nymphaeae*, cornicle of alate form.
- JJ.—*Rhopalosiphum nymphaeae*, cauda of alate form.
- KK.—*Pergandeidia ononidis*, cauda and cornicle of alate form.
- LL.—*Pergandeidia trirhodus*, cauda of apterous form.
- MM.—*Pergandeidia trirhodus*, cornicle of apterous form.
- NN.—*Liosomaphis berberidis*, cornicle and cauda of apterous form.
- OO.—*Liosomaphis berberidis*, cauda of alate form.
- PP.—*Cryptosiphum artemesiae*, cornicle of apterous form.
- QQ.—*Cryptosiphum artemesiae*, cauda of apterous form.
- RR.—*Hyalopterus arundinis*, cornicle of alate form.
- SS.—*Hyalopterus arundinis*, cauda of alate form.
- TT.—*Hyalopterus deformans*, cauda of apterous form.
- UU.—*Hyalopterus deformans*, cornicle of apterous form.
- VV.—*Hyalopterus deformans*, cauda of alate form.
- WW.—*Hyalopterus deformans*, cornicle of alate form.

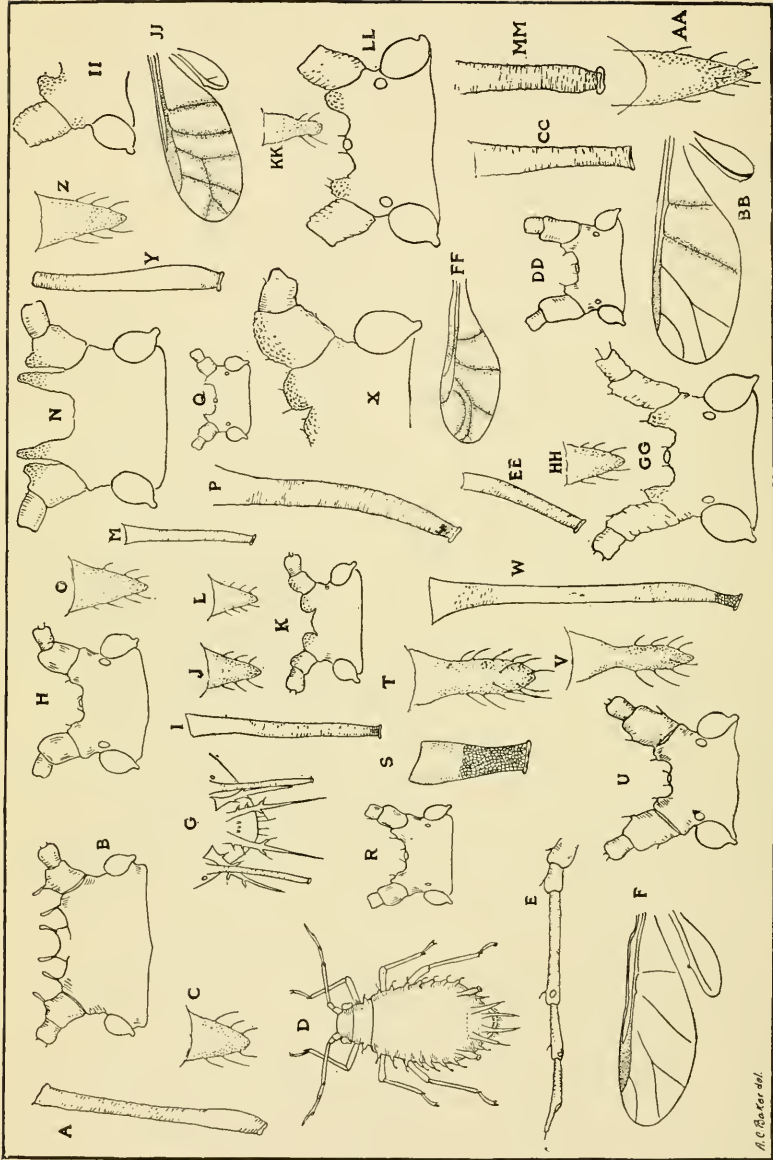
PLATE VII.

- A.—*Siphonatrophia cupressi*, apterous form.
- B.—*Siphonatrophia cupressi*, wings.
- C.—*Siphonatrophia cupressi*, antenna of alate form.
- D.—*Siphonatrophia cupressi*, cauda of alate form.
- E.—*Siphonatrophia cupressi*, antenna of apterous form.
- F.—*Sanbornia juniperi*, apterous form.
- G.—*Sanbornia juniperi*, wings.
- H.—*Sanbornia juniperi*, antenna of alate form.
- I.—*Sanbornia juniperi*, head of apterous form from beneath.
- J.—*Sanbornia juniperi*, cauda of alate form.
- K.—*Sanbornia juniperi*, cornicle.
- L.—*Sanbornia juniperi*, tarsus.
- M.—*Vesiculaphis caricis*, apterous form.
- N.—*Vesiculaphis caricis*, cornicle of alate form.
- O.—*Vesiculaphis caricis*, fore wing.
- P.—*Vesiculaphis caricis*, antenna of alate form.
- Q.—*Vesiculaphis caricis*, cauda of alate form.
- R.—*Acanthaphis rubi*, apterous form.
- S.—*Acanthaphis rubi*, head of apterous form.
- T.—*Acanthaphis rubi*, cornicle of apterous form.
- U.—*Acanthaphis rubi*, antenna of apterous form.



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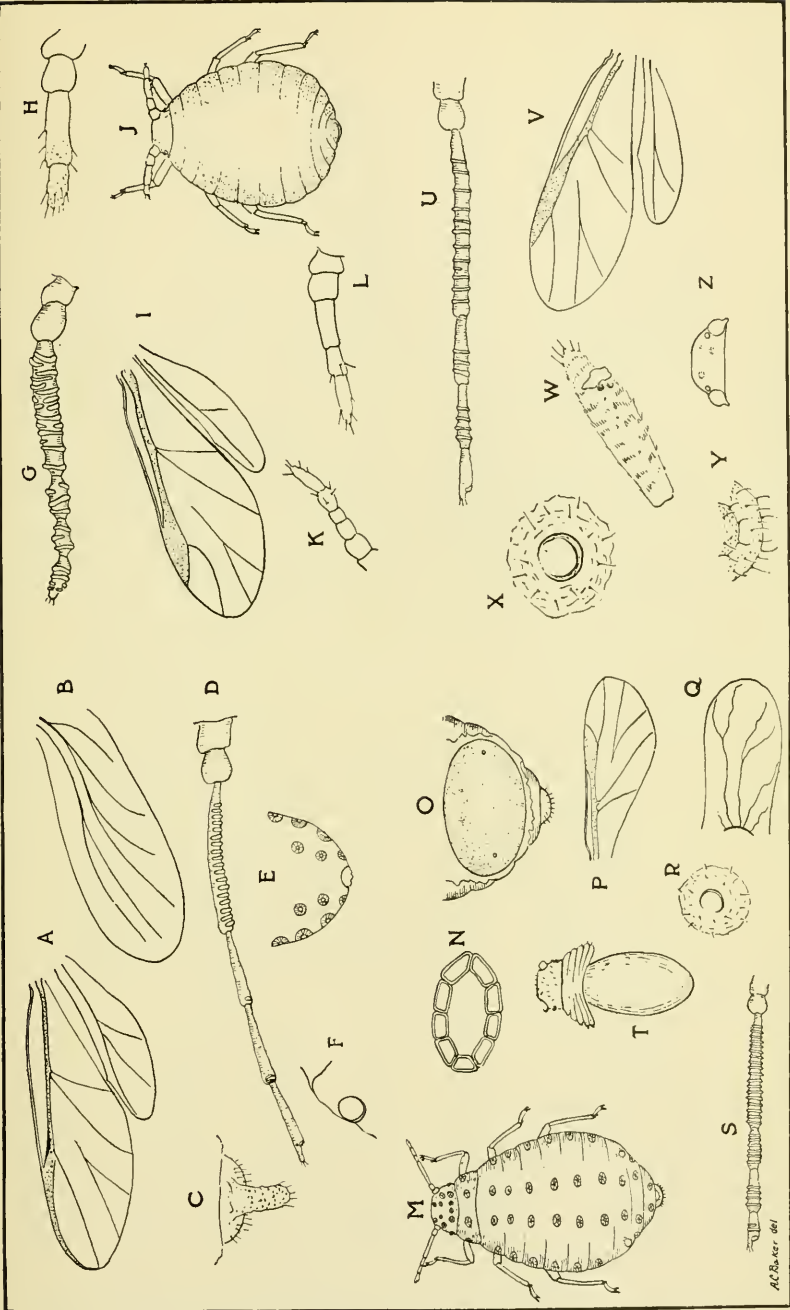
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PLATE VIII.

- A.—*Capitophorus shepardiae*, cornicle of alate form.
- B.—*Capitophorus shepardiae*, head of alate form.
- C.—*Capitophorus shepardiae*, cauda of alate form.
- D.—*Anomalaphis comperi*, apterous form.
- E.—*Anomalaphis comperi*, antenna of apterous form.
- F.—*Anomalaphis comperi*, wings.
- G.—*Cervaphis schoutedeniae*, extremity of abdomen.
- H.—*Illinoia liriiodendri*, head of alate form.
- I.—*Illinoia liriiodendri*, cornicle of alate form.
- J.—*Illinoia liriiodendri*, cauda of alate form.
- K.—*Myzus cerasi*, head of apterous form.
- L.—*Myzus cerasi*, cauda of apterous form.
- M.—*Myzus cerasi*, cornicle of alate form.
- N.—*Phorodon humuli*, head of apterous form.
- O.—*Phorodon humuli*, cauda of apterous form.
- P.—*Phorodon humuli*, cornicle of apterous form.
- Q.—*Phorodon humuli*, head of alate form.
- R.—*Macrosiphonella sanborni*, head of alate form.
- S.—*Macrosiphonella sanborni*, cornicle of alate form.
- T.—*Macrosiphonella sanborni*, cauda of alate form.
- U.—*Macrosiphum rosae*, head of alate form.
- V.—*Macrosiphum rosae*, cauda of alate form.
- W.—*Macrosiphum rosae*, cornicle of alate form.
- X.—*Myzus persicae*, head of apterous form.
- Y.—*Myzus persicae*, cornicle of alate form.
- Z.—*Myzus persicae*, cauda of alate form.
- AA.—*Microparsus variabilis*, cauda of alate form.
- BB.—*Microparsus variabilis*, wings.
- CC.—*Microparsus variabilis*, cornicle of alate form.
- DD.—*Microparsus variabilis*, head of alate form.
- EE.—*Idiopterus nephrolepidis*, cornicle of alate form.
- FF.—*Idiopterus nephrolepidis*, fore wing.
- GG.—*Idiopterus nephrolepidis*, head of alate form.
- HH.—*Idiopterus nephrolepidis*, cauda of alate form.
- II.—*Pentalonia nigronervosa*, head of apterous form.
- JJ.—*Pentalonia nigronervosa*, wings.
- KK.—*Pentalonia nigronervosa*, cauda of alate form.
- LL.—*Pentalonia nigronervosa*, head of alate form.
- MM.—*Pentalonia nigronervosa*, cornicle of alate form.

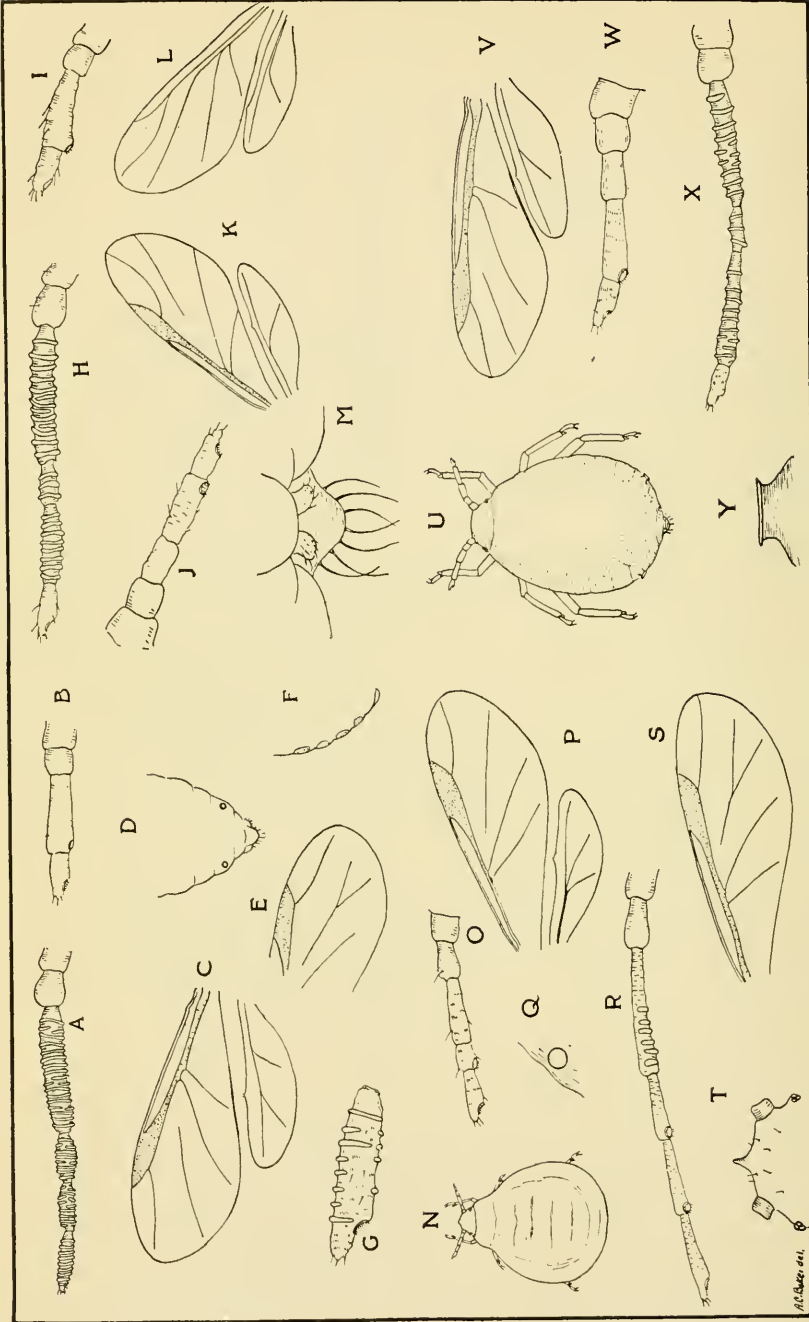
PLATE IX.

- A.—*Mindarus abietinus*, wings.
- B.—*Mindarus abietinus*, fore wing showing tracheæ.
- C.—*Mindarus abietinus*, cauda of alate form.
- D.—*Mindarus abietinus*, antenna of alate form.
- E.—*Mindarus abietinus*, abdomen of pupa.
- F.—*Mindarus abietinus*, cornicle of alate form.
- G.—*Colopha ulmicola*, antenna of alate form.
- H.—*Colopha ulmicola*, antenna of stem mother.
- I.—*Colopha ulmicola*, wings.
- J.—*Colopha ulmicola*, apterous form.
- K.—*Colopha ulmicola*, antenna of apterous form.
- L.—*Colopha ulmicola*, antenna of apterous form.
- M.—*Eriosoma lanigerum*, apterous form.
- N.—*Eriosoma lanigerum*, wax plate.
- O.—*Eriosoma lanigerum*, wax reservoir.
- P.—*Eriosoma lanigerum*, fore wing.
- Q.—*Eriosoma lanigerum*, wing pad showing tracheæ.
- R.—*Eriosoma lanigerum*, cornicle.
- S.—*Eriosoma lanigerum*, antenna of alate form.
- T.—*Eriosoma lanigerum*, oviparous female, showing egg.
- U.—*Georgia ulmi*, antenna of alate form.
- V.—*Georgia ulmi*, wings.
- W.—*Georgia ulmi*, distal segment of antenna of alate form.
- X.—*Georgia ulmi*, cornicle of alate form.
- Y.—*Georgia ulmi*, cauda and anal plate of alate form.
- Z.—*Georgia ulmi*, head of alate form.



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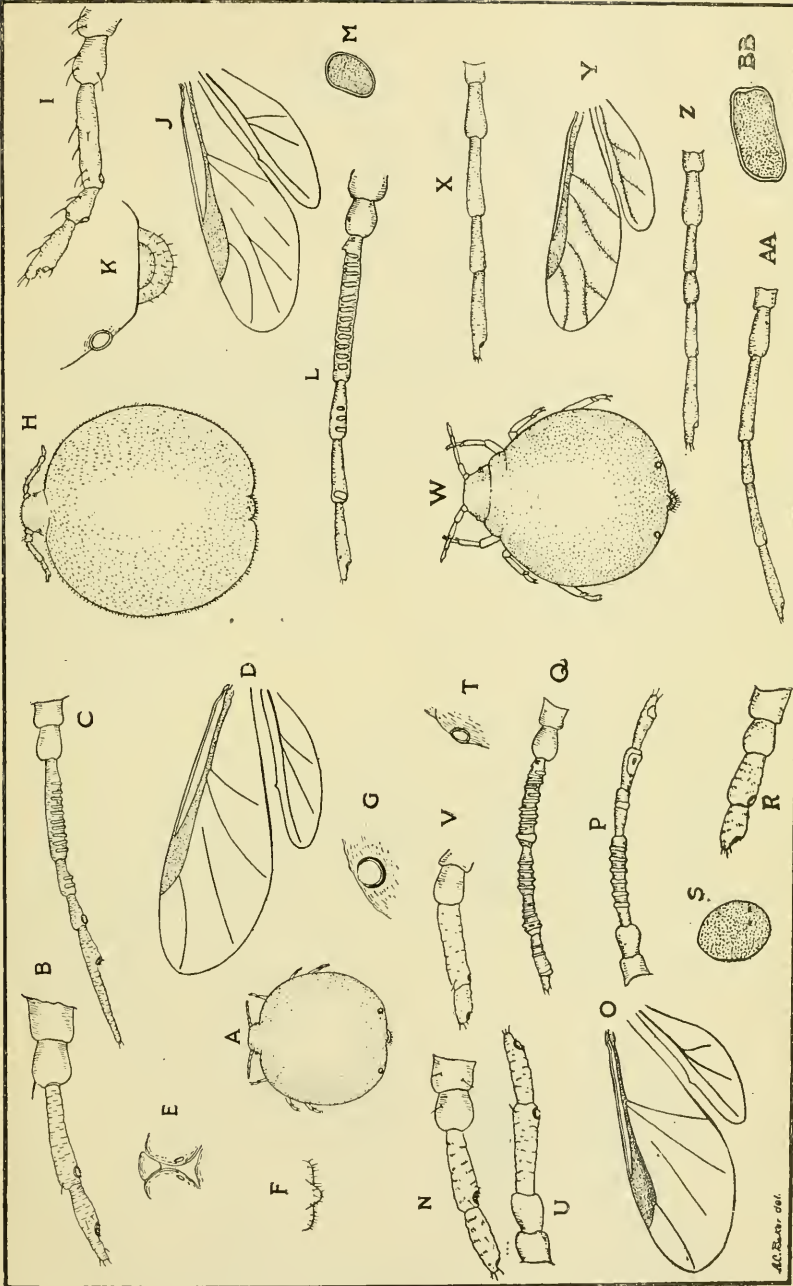
GENERIC CLASSIFICATION OF APHIDIDAE.

PLATE X.

- A.—*Gobaishia pallida*, antenna of alate form.
- B.—*Gobaishia pallida*, antenna of stem mother.
- C.—*Gobaishia pallida*, wings.
- B.—*Gobaishia pallida*, abdomen of alate form showing cornicle.
- E.—*Gobaishia pallida*, fore wing.
- F.—*Gobaishia pallida*, abdomen of pupa.
- G.—*Gobaishia pallida*, distal segment of antenna of alate form from above.
- H.—*Tetraneura ulmifoliae*, antenna of alate form.
- I.—*Tetraneura ulmifoliae*, antenna of stem mother.
- J.—*Tetraneura ulmifoliae*, antenna of apterous form.
- K.—*Tetraneura ulmifoliae*, wings.
- L.—*Tetraneura ulmifoliae*, wings showing tracheæ.
- M.—*Tetraneura ulmifoliae*, cauda and anal plate.
- N.—*Cornaphis populi*, stem mother.
- O.—*Cornaphis populi*, antenna of stem mother.
- P.—*Cornaphis populi*, wings.
- Q.—*Cornaphis populi*, cornicle of alate form.
- R.—*Cornaphis populi*, antenna of alate form.
- S.—*Cornaphis populi*, fore wing.
- T.—*Cornaphis populi*, head showing horn.
- U.—*Dryopeia bella*, apterous form.
- V.—*Dryopeia bella*, wings.
- W.—*Dryopeia bella*, antenna of apterous form.
- X.—*Dryopeia bella*, antenna of alate form.
- Y.—*Dryopeia bella*, cornicle of apterous form.

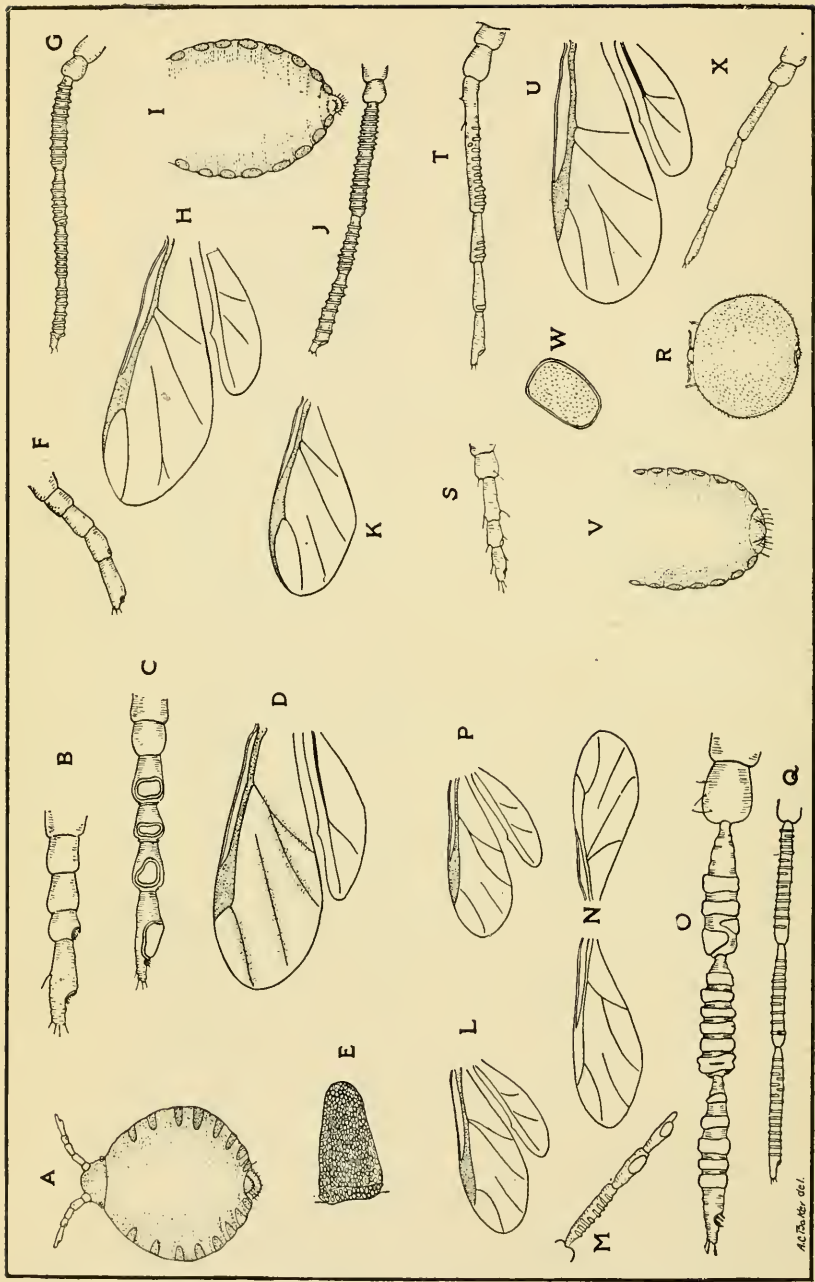
PLATE XI.

- A.—*Mordwilkoja vagabunda*, stem mother.
- B.—*Mordwilkoja vagabunda*, antenna of stem mother.
- C.—*Mordwilkoja vagabunda*, antenna of alate form.
- D.—*Mordwilkoja vagabunda*, wings.
- E.—*Mordwilkoja vagabunda*, thorax of alate form.
- F.—*Mordwilkoja vagabunda*, cauda of alate form.
- G.—*Mordwilkoja vagabunda*, cornicle of alate form.
- H.—*Asiphum* sp. stem mother.
- I.—*Asiphum* sp. antenna of stem mother.
- J.—*Pachypappella vesicalis*, wings.
- K.—*Pachypappella vesicalis*, cornicles and cauda of alate form.
- L.—*Pachypappella vesicalis*, antenna of alate form.
- M.—*Pachypappella vesicalis*, wax plate.
- N.—*Pemphigus bursarius*, antenna of stem mother.
- O.—*Pemphigus bursarius*, wings.
- P.—*Pemphigus bursarius*, antenna of alate form.
- Q.—*Pemphigus bursarius*, antenna of alate form.
- R.—*Pemphigus bursarius*, antenna of stem mother.
- S.—*Pemphigus bursarius*, wax plate.
- T.—*Pemphigus bursarius*, cornicle of alate form.
- U.—*Pemphigus populicaulis*, antenna of stem mother.
- V.—*Gobaishia ulmifuscus*, antenna of stem mother.
- W.—*Phloeomyzus passerini*, apterous form.
- X.—*Phloeomyzus passerini*, antenna of apterous form.
- Y.—*Phloeomyzus passerini*, wings.
- Z.—*Phloeomyzus passerini*, antenna of apterous form.
- AA.—*Phloeomyzus passerini*, antenna of alate form.
- BB.—*Phloeomyzus passerini*, wax plate.



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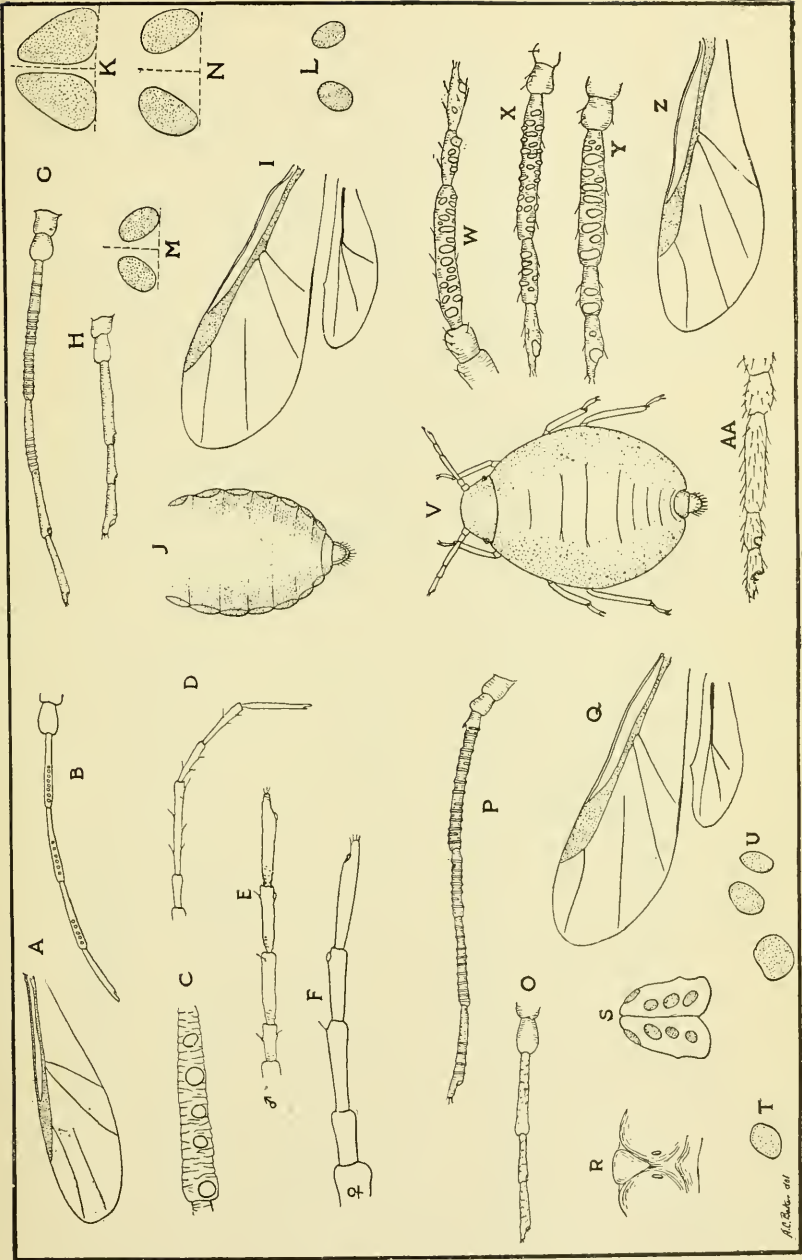
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PLATE XII.

- A.—*Aploneura lentici*, apterous form.
- B.—*Aploneura lentici*, antenna of apterous form.
- C.—*Aploneura lentici*, antenna of alate form.
- D.—*Aploneura lentici*, wings.
- E.—*Aploneura lentici*, abdominal wax plate.
- F.—*Melaphis rhois*, antenna of apterous form.
- G.—*Melaphis rhois*, antenna of alate form.
- H.—*Melaphis rhois*, wings.
- I.—*Melaphis rhois*, abdomen of alate form.
- J.—*Melaphis rhois*, antenna of alate form.
- K.—*Melaphis chinensis*, fore wing.
- L.—*Nurudea ibofushi*, wings.
- M.—*Nurudea ibofushi*, antenna of alate form.
- N.—*Nurudea shiraii*, wings.
- O.—*Nurudea shiraii*, antenna of alate form.
- P.—*Nurudea rosea*, fore wing.
- Q.—*Nurudea rosea*, antenna of alate form.
- R.—*Asiphum tremulae*, stem mother.
- S.—*Asiphum tremulae*, antenna of stem mother.
- T.—*Asiphum tremulae*, antenna of alate form.
- U.—*Asiphum tremulae*, wings.
- V.—*Asiphum tremulae*, abdomen of alate form.
- W.—*Asiphum tremulae*, wax plates.
- X.—*Asiphum tremulae*, antenna of apterous form.

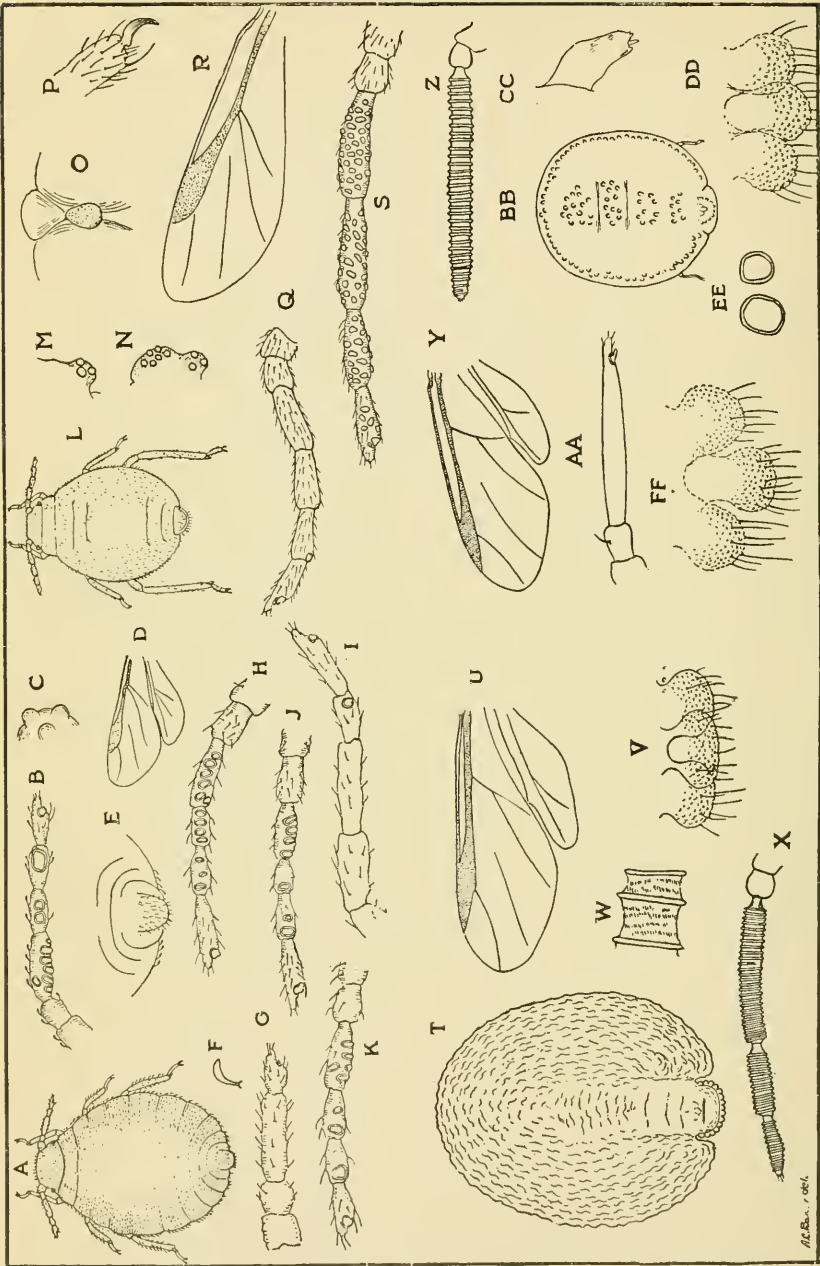
PLATE XIII.

- A.—*Neoprociphilus attenuatus*, forewing.
- B.—*Neoprociphilus attenuatus*, antenna of alate form.
- C.—*Neoprociphilus attenuatus*, segment V of antenna of alate form.
- D.—*Neoprociphilus attenuatus*, antenna of apterous form.
- E.—*Neoprociphilus attenuatus*, antenna of male.
- F.—*Neoprociphilus attenuatus*, antenna of oviparous female.
- G.—*Prociphilus bumeliae*, antenna of alate female.
- H.—*Prociphilus bumeliae*, antenna of stem mother.
- I.—*Prociphilus bumeliae*, wings.
- J.—*Prociphilus bumeliae*, abdomen of alate form.
- K.—*Prociphilus bumeliae*, thoracic wax plates.
- L.—*Prociphilus bumeliae*, head wax plates.
- M.—*Prociphilus xylostei*, thoracic wax plates.
- N.—*Prociphilus bumeliae* (*poscheringi*), thoracic wax plates.
- O.—*Thecabius affinis*, antenna of stem mother.
- P.—*Thecabius affinis*, antenna of alate form.
- Q.—*Thecabius affinis*, wings.
- R.—*Thecabius affinis*, thorax of alate form.
- S.—*Thecabius affinis*, head wax plates of stem mother.
- T.—*Thecabius affinis*, abdominal wax plate.
- U.—*Thecabius affinis*, abdominal wax plates of stem mother.
- V.—*Forda* sp., apterous form.
- W.—*Forda olivacea*, antenna of alate form.
- X.—*Forda trivialis*, antenna of alate form.
- Y.—*Forda marginata*, antenna of alate form.
- Z.—*Forda olivacea*, fore wing.
- AA.—*Forda formicaria*, antenna of apterous form.



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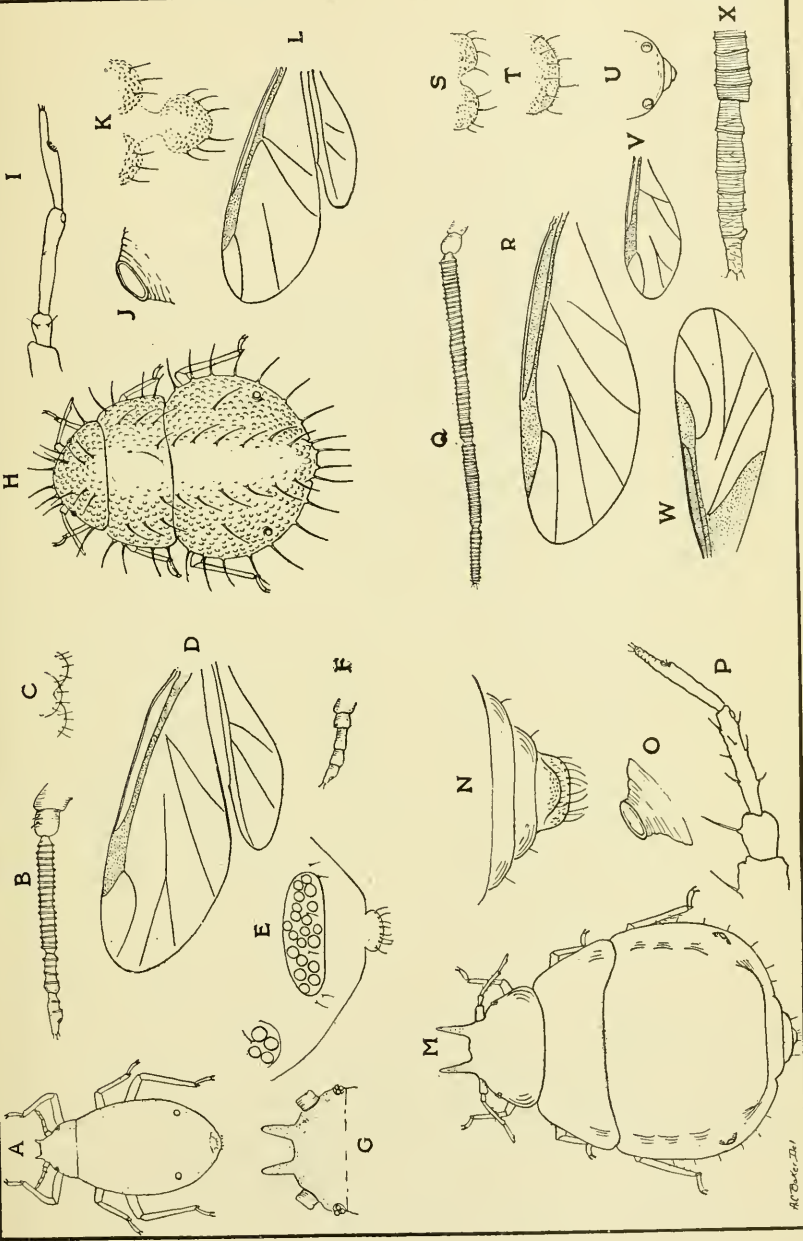
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PLATE XIV.

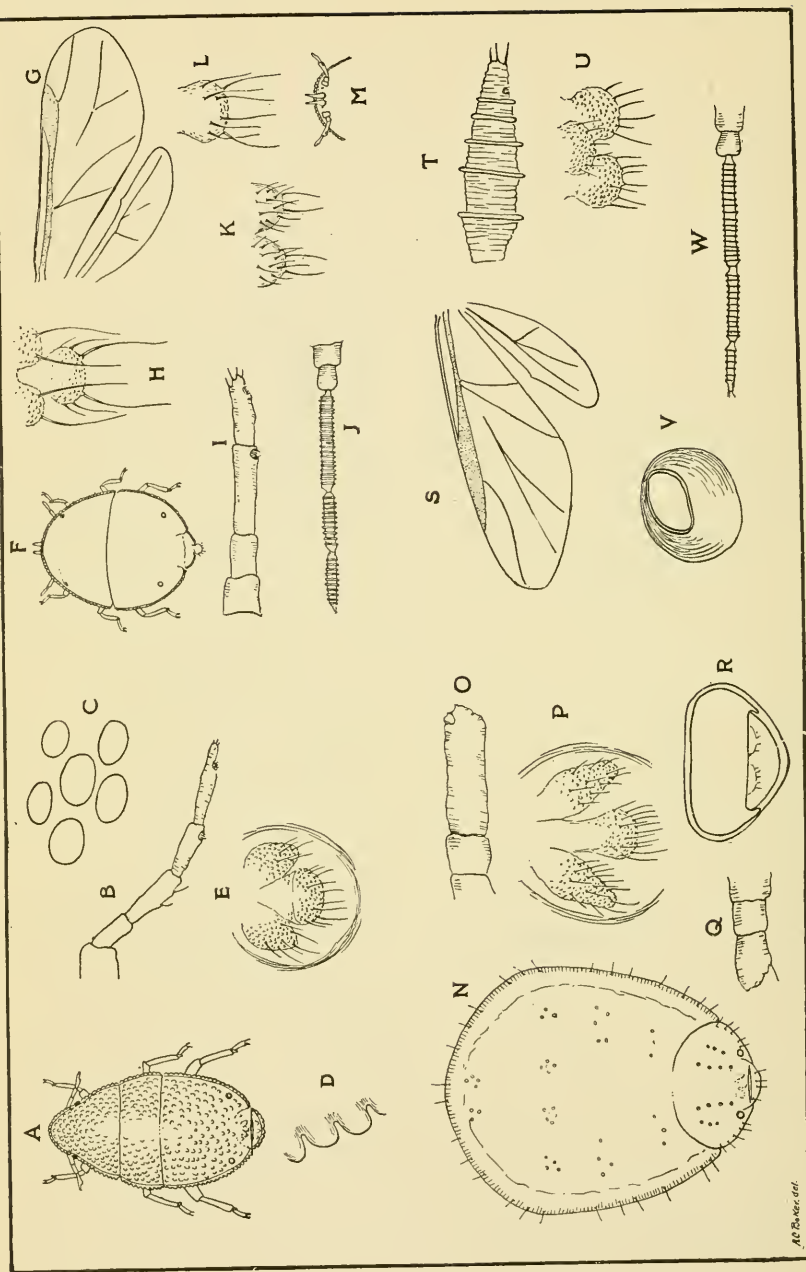
- A.—*Geoica squamosa*, apterous form.
- B.—*Geoica squamosa*, antenna of alate form.
- C.—*Geoica squamosa*, eye of apterous form.
- D.—*Geoica squamosa*, wings.
- E.—*Geoica squamosa*, caudal extremity of apterous form.
- F.—*Geoica squamosa*, squama.
- G.—*Geoica squamosa*, four-segmented antenna of apterous form.
- H.—*Geoica phaseoli*, antenna of alate form.
- I.—*Geoica phaseoli*, antenna of apterous form.
- J.—*Geoica radīcicola*, antenna of alate form.
- K.—*Geoica lucifuga*, antenna of alate form.
- L.—*Paracletus cimiciformis*, apterous form.
- M.—*Paracletus cimiciformis*, eye of apterous form.
- N.—*Paracletus cimiciformis*, intermediate eye.
- O.—*Paracletus cimiciformis*, median thoracic wax plate of alate form.
- P.—*Paracletus cimiciformis*, foot of alate form with one claw.
- Q.—*Paracletus cimiciformis*, antenna of apterous form.
- R.—*Paracletus cimiciformis*, forewing.
- S.—*Paracletus cimiciformis*, antenna of alate form.
- T.—*Hamamelistes spinosus*, hibernating apterous form.
- U.—*Hamamelistes spinosus*, wings.
- V.—*Hamamelistes spinosus*, cauda and anal plate of alate form.
- W.—*Hamamelistes spinosus*, antenna of alate form.
- X.—*Hamamelistes spinosus*, portion of same, more enlarged.
- Y.—*Hormaphis hamamelidis*, wings.
- Z.—*Hormaphis hamamelidis*, antenna of alate form.
- AA.—*Hormaphis hamamelidis*, antenna of stem mother.
- BB.—*Hormaphis hamamelidis*, apterous form.
- CC.—*Hormaphis hamamelidis*, antenna of apterous form.
- DD.—*Hormaphis hamamelidis*, cauda and anal plate of apterous form.
- EE.—*Hormaphis hamamelidis*, dorsal wax pores.
- FF.—*Hormaphis hamamelidis*, cauda and anal plate of alate form.

PLATE XV.

- A.—*Oregma lanigera*, apterous form.
- B.—*Oregma lanigera*, antenna of alate form.
- C.—*Oregma lanigera*, cauda and anal plate of alate form.
- D.—*Oregma lanigera*, wings.
- E.—*Oregma lanigera*, end of abdomen of apterous form.
- F.—*Oregma lanigera*, antenna of apterous form.
- G.—*Oregma bambusae*, head of apterous form.
- H.—*Glyphinaphis bambusae*, apterous form.
- I.—*Glyphinaphis bambusae*, antenna of apterous form.
- J.—*Glyphinaphis bambusae*, cornicle of apterous form.
- K.—*Glyphinaphis bambusae*, cauda and anal plate.
- L.—*Mansakia miyabei*, wings.
- M.—*Ceratoglyphina bambusae*, apterous form.
- N.—*Ceratoglyphina bambusae*, cauda and anal plate.
- O.—*Ceratoglyphina bambusae*, cornicle of apterous form.
- P.—*Ceratoglyphina bambusae*, antenna of apterous form.
- Q.—*Astegopteryx distychii*, antenna of alate form.
- R.—*Astegopteryx distychii*, fore wing.
- S.—*Astegopteryx distychii*, anal plate of alate form.
- T.—*Astegopteryx distychii*, cauda of alate form.
- U.—*Astegopteryx distychii*, end of abdomen.
- V.—*Astegopteryx styracophila*, fore wing.
- W.—*Astegopteryx gallarum*, fore wing.
- X.—*Astegopteryx gallarum*, tip of antenna of alate form.



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PLATE XVI.

- A.—*Aleurodaphis blumeae*, apterous form.
- B.—*Aleurodaphis blumeae*, antenna of apterous form.
- C.—*Aleurodaphis blumeae*, dorsal wax pores.
- D.—*Aleurodaphis blumeae*, margin.
- E.—*Aleurodaphis blumeae*, cauda and anal plate.
- F.—*Cerataphis lataniae*, apterous form.
- G.—*Cerataphis lataniae*, wings.
- H.—*Cerataphis lataniae*, cauda and anal plate of apterous form.
- I.—*Cerataphis lataniae*, antenna of apterous form.
- J.—*Cerataphis lataniae*, antenna of alate form.
- K.—*Cerataphis lataniae*, anal plate of alate form.
- L.—*Cerataphis lataniae*, cauda of alate form.
- M.—*Cerataphis lataniae*, head of apterous form, central view.
- N.—*Thoracaphis arboris*, apterous form.
- O.—*Thoracaphis arboris*, antenna of apterous form.
- P.—*Thoracaphis arboris*, cauda and anal plate of apterous form.
- Q.—*Thoracaphis ficus*, antenna of apterous form.
- R.—*Thoracaphis ficus*, extremity of abdomen, apterous form.
- S.—*Thoracaphis castaneae*, wings.
- T.—*Thoracaphis castaneae*, distal segment of antenna of alate form.
- U.—*Thoracaphis castaneae*, cauda and anal plate of alate form.
- V.—*Thoracaphis castaneae*, cornicle of alate form.
- W.—*Thoracaphis castaneae*, antenna of alate form.

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L. O. HOWARD, Chief.

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CHRYSANTHEMUM MIDGE.¹

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GENERAL DESCRIPTION.

The chrysanthemum midge, *Diarthronomyia hypogaeu* (F. Löw), is a European insect which gained entrance into the United States a few years ago and since then has been reported as injurious from widely separated localities in this country and Canada.

When chrysanthemums are infested by this midge, the attention of the casual observer is most likely to be drawn to the presence of galls. These galls occur on the leaf, stem, or flower head of the chrysanthemum plant. (See Pl. I, B and C.) After the larvæ hatch from the orange-colored eggs, which are deposited by the adult female on the surface of tender tips and new growth, they bore their way into the tissues, thereby giving rise to the galls.

The galls are cone-shaped and generally project obliquely from the surface. The length of the gall when fully developed is about one-

¹ The account of the chrysanthemum midge contained in this bulletin is the result of an investigation which was undertaken with the intention of providing further data on the life history and habits of this insect, as well as more satisfactory means of control. The preliminary life-history studies which were started in February, 1917, by A. D. Borden, of the Bureau of Entomology, were subsequently taken up by H. F. Dietz, of the Federal Horticultural Board. Further studies on life history and control were inaugurated and carried to completion by the writers as a result of the many inquiries for advice as well as the outbreaks reported during the chrysanthemum season of 1918 and the spring of 1919. During the entire period the work has been under the constant supervision of E. R. Sasser, chief inspector of the Federal Horticultural Board and collaborator of the Bureau of Entomology.

twelfth of an inch. When the leaf is affected, the galls usually occur on the upper surface. In such cases a slight swelling often may be observed on the opposite or under side of the leaf. Growth and development of both larva and pupa take place within this gall. When the pupa is fully developed it pushes itself out of the gall, still inclosed in the pupal skin. The latter then splits down the middle of the head and back to allow the adult to emerge. (See Pl. II, C.)

In the adult stage the midge is a fragile two-winged fly, one-fourteenth inch in length. The abdomen of the male is yellowish orange, while that of the female is reddish orange. The adult on emerging leaves its pupal skin protruding from the opening of the empty gall. (See Pl. II, A.) As shown in the life-history studies, the adults emerge after midnight and egg-laying takes place early in the morning.

HISTORICAL.

In 1870, E. Perris (1, p. 177)¹ is recorded as having observed cecidomyiid larvæ on *Leucanthemum vulgare*. Six years later J. E. Von Bergenstamm and P. Löw (2) also recorded larvæ which in all probability were cecidomyiid, as they were found attacking the young leaves of *Chrysanthemum leucanthemum* (*Leucanthemum vulgare*.) In August, 1875, E. Berroyer collected specimens in Raxalpa, a group of the Eastern Alps of Austria-Hungary, at an elevation of 5,000 feet above sea level. These specimens, which consisted of subterranean galls, and two adult male midges, were submitted to Franz Löw (3) by Von Bergenstamm. Franz Löw made the original description in 1885, which freely translated is as follows:

Male: Antennæ 2-14 jointed. Peduncle shorter than the segments. Terminal segment with two whorls of stout setæ. Wings cloudy white. All veins, also costal vein white. Second parallel vein straight, disappearing in the apex of the wings. First branch of the third parallel vein so weak that it is not visible, unless under best of light and high power, but the wing fold on the other hand is very plainly discernible. Halteres white. Legs with closely adhering hairs, also appearing white.

Larva: The still unknown larva causes galls on the underground parts of the stem of *Chrysanthemum atratum* Jacq., in which their complete transformation takes place. In each are also found several larvæ, each larva occupying one cell for itself.

Pupa: The pupa has (like the pupa of the *Asphondylia* species) three pairs of horns, but on the other hand, lacks the rows of delicate horns found on the dorsal surface of abdominal segments of the *Asphondylia* species.

The two cephalic horns are very large, widely separated, slender, quite pointed and with the point somewhat recurved. The horns of both other pairs are very small, alike in size and structure, pointed and also with the point somewhat recurved. They occur in such a manner that a horn is located above and below each eye of the pupa; consequently, the horns of one pair are widely separated from each other. In the cells of the galls in which pupation of the larva takes place, the pupæ are so situated that the head points to the periphery of the gall.

¹ Numbers in parentheses refer to "Literature cited," p. 23.

Galls: They occur, three or four in number, at the extremity of the upper and lower surfaces of the stem of the *Chrysanthemum atratum* Jacq., which is irregularly rounded, varying in size from a large hemp seed to a large pea. Outside naked, consisting of a fleshy homogeneous mass in which occur small, elongated cells or chambers each being inhabited by a larva.

Distribution: On Raxalpa about 5,000 feet above sea level. (E. Berroyer.)

From this date, until it was first reported by Felt in the United States, frequent references are found in literature relating to its occurrence and synonymy. Among these may be listed the following: Rübsaamen (4, p. 375), Kieffer (5, p. 21), (6), (7, p. 351, 353), (13), Baldrati (8, p. 40-41), Kertész (9, p. 69), Houard (11), and Küster (12, p. 77, 274).

On March 26, 1915, R. H. Pettit of the Michigan Agricultural College had his attention called to the existence of an infestation occurring in large chrysanthemum houses at Adrian, Mich. Specimens were submitted to E. P.

Felt (14), State entomologist of New York, who in April of that year determined it as the chrysanthemum midge, *Diarthronomyia hypogaea* (F. Löw). In 1916 A. Gibson (21) reported the occurrence of the midge at Ottawa, Canada. Subsequently, reports of its occurrence have

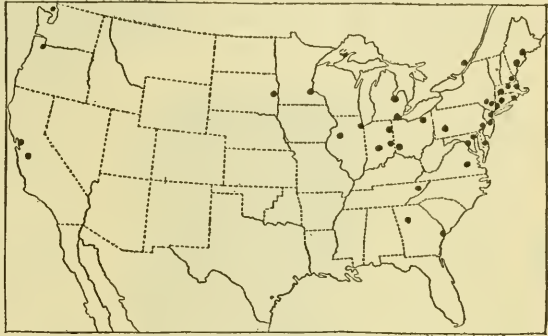


FIG. 1.—Map showing distribution of the chrysanthemum midge in the United States and Canada.

been received from widely separated points, both in the United States and Canada. According to California florists, this pest has been present in that State for about 15 years.

DISTRIBUTION IN THE UNITED STATES AND CANADA.

To date, the midge has been reported from California, Connecticut, Delaware, the District of Columbia, Georgia, Illinois, Indiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, New Hampshire, New Jersey, New York, Ohio, Oregon, Pennsylvania, Rhode Island, South Dakota, Tennessee, and Virginia, as well as from Ottawa and Victoria, in Canada.

Since the first records of its occurrence and seriousness were reported from the Middle West it would appear that the distribution of infested plants from this region was the source of its further spread to the other sections of the United States and Canada.

Its distribution, as indicated on the accompanying map (fig.1), is almost wholly confined to the larger chrysanthemum-growing regions of the United States, which include the areas surrounding the Great

Lakes and the northern and central Atlantic seaboard. On the Pacific coast it is reported from California and Oregon, and its presence has been confirmed in South Dakota, Tennessee, and Georgia. Doubtless a careful survey would locate many additional isolated infestations which have not been brought to the attention of State or Federal entomologists.

VARIETIES AFFECTED.

While the chrysanthemum midge has been recorded from central and southern Europe as seriously injuring the common white or ox-eye daisy (*Chrysanthemum leucanthemum*), as well as *C. corymbosum*, *C. atratum*, *C. japonicum*, and *C. myconis* (11), its depredations in North America are confined to practically all of the commercial chrysanthemums, both the single and pompon varieties. The first infestation in this country was reported on the variety Mistletoe, and according to Felt (14, 15, 16) this variety appears to be very susceptible to the attacks of the midge.

Although several attempts have been made to infest the Shasta daisy and the common field daisy, *C. leucanthemum*, it has not been possible to get the ovipositing female to lay eggs on them. This is of much importance, for should the infestation spread to this common weed, there would be great difficulty in eradicating this pest.

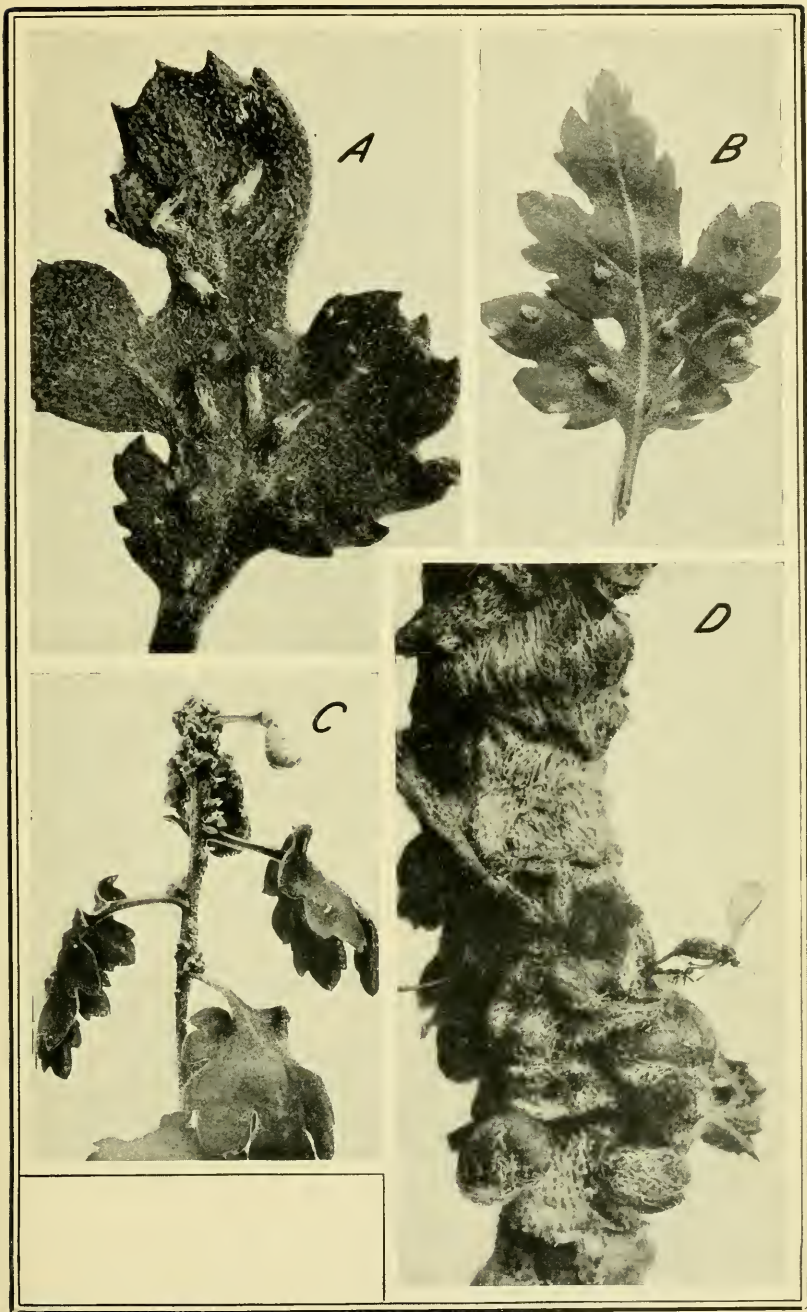
A. Gibson lists the following varieties as being fairly free from injury: Bob Pulling, Gertrude Peers, Daily Mail, Oconta, Mrs. G. C. Kelly, W. Wood Mason, F. T. Quilleton, and E. T. Quittington. All the above varieties are the blended product of *C. indicum* and *C. morifolium*, both of which grow wild in China and Japan. He reports the following varieties as being practically ruined: Smith's Advance, Ivory, Bonnaffon, Wm. Turner, Western King, and Englehart.

Observations made by H. F. Dietz in the Middle West showed that the Wm. Turner variety had lost all the crown buds. In case of a thick infestation on the variety Dr. Enguehard all of the plants had to be discarded early in the season; also all Chadwick varieties, as well as Elberon, Major Bonnaffon, and Golden Mensa. The varieties which seemed to be least injured were Golden Age, Harvard, and White Bonnaffon.

In some of the greenhouses of the District of Columbia during the season of 1918-1919 such varieties as Mensa, William Turner, and the white and yellow Bonnaffon were completely ruined on account of the severe infestation.

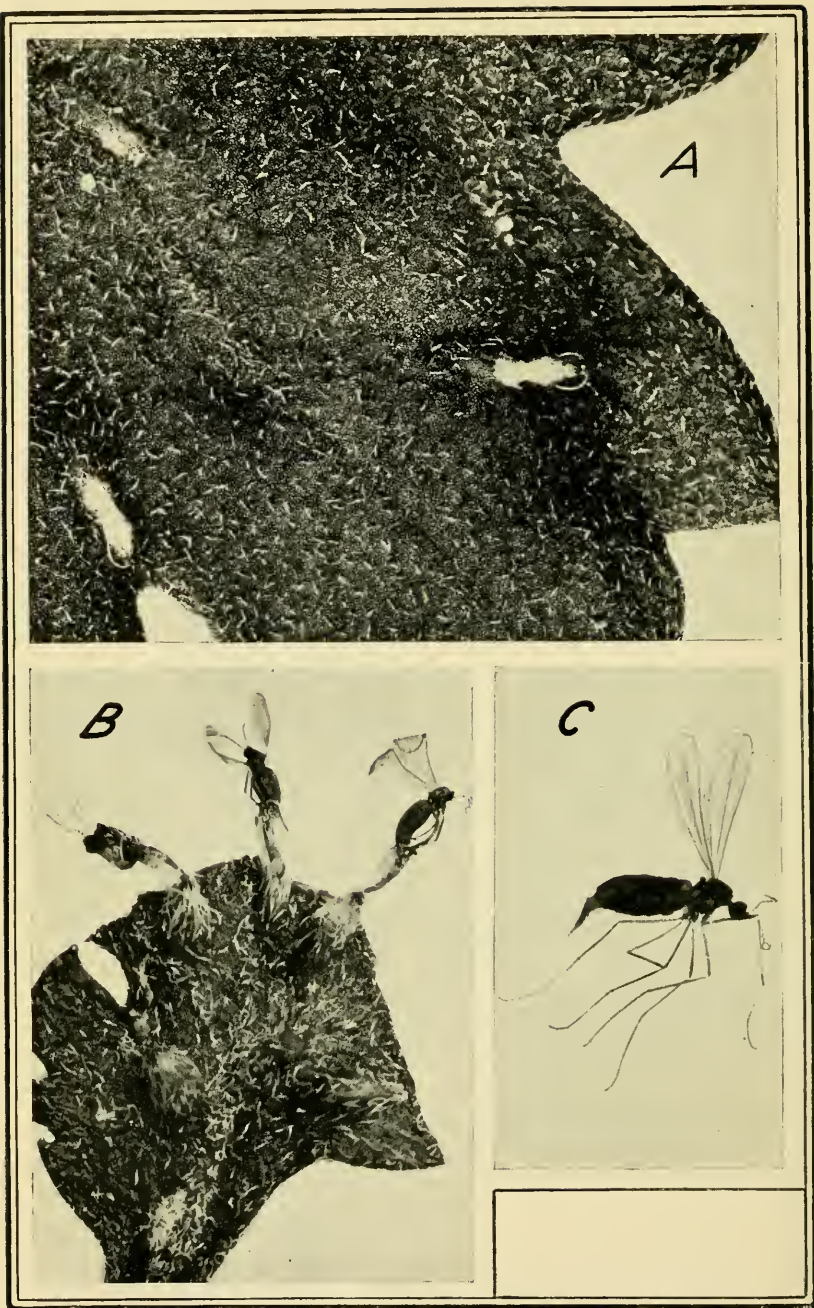
ECONOMIC IMPORTANCE.

Although a comparatively recent introduction this insect now seems to be firmly established in the United States and is one of the most important pests to be reckoned with by chrysanthemum growers.



THE CHRYSANTHEMUM MIDGE.

A, Adults emerging. *B*, galls of midge on chrysanthemum leaf. *C*, injury to terminal growth.
D, adult emerging from stem gall.



THE CHRYSANTHEMUM MIDGE.

A, Empty pupal skins protruding from galls after emergence of adults. *B*, adults killed while emerging as a result of being sprayed with nicotine sulphate. *C*, adult female midge.

While it is primarily a greenhouse pest, A. Gibson, in August, 1915, found it occurring on both greenhouse and outdoor plants at Ottawa, Canada. Well-developed galls on the newly unfolded leaves were found by the authors, March 26, 1919, on hardy chrysanthemums which had been grown out of doors all winter at the Arlington Farm, Rosslyn, Va. A careful inspection of the entire stock revealed the fact that the insects had wintered over on these plants in the immature stages, probably as either larvæ or pupæ within the galls. Inasmuch as there were many empty galls present on the old dead and dried leaves of the previous season's growth, it was evident that this was an infestation of long standing. On April 11, many adults were found entangled in webbing spun by spiders among the developing new tip growth. These emerged from the above mentioned galls.

The first severe infestation of the midge brought to the attention of the Bureau of Entomology was on chrysanthemums in greenhouses at Philadelphia, April, 1917. The entire stock was infested, causing a total loss to the grower. During the same year other florists reported a total loss of their stock of chrysanthemums valued at several thousand dollars. Even in the case of a light infestation the foliage is practically valueless for commercial purposes, and in the case of a heavy infestation the growth is completely arrested. (See Pl. I, C.)

Owing to numerous reports of injury by the chrysanthemum midge in the States of Indiana, Illinois, and Michigan, H. F. Dietz conducted a survey in this territory during the months of November and December, 1918, for the purpose of ascertaining the exact amount of damage occasioned by this pest. From the data gathered, this general locality proved to be one of the centers from which the pest was being distributed over the United States. Greenhouses of 33 florists were visited, including some of the largest growers and distributors in this country. It was evident that if serious pests were established in this region, it would be only a matter of a year or two before such insects would be widely scattered. This is exactly what has happened in the case of the chrysanthemum midge. This pest was found established in 8 of 33 places visited.

Serious injury to infested plants was noted. For example, no plants of the variety Dr. Enguehard came into flower, on account of their dwarfed, knotted, and knarled condition, with the result that the new central stem did not form. Moreover, other varieties, including Wm. Turner, were attacked just at the time the crown buds were "setting," causing these flowers to become distorted. As a result, the flowers are not borne upright as normal flowers should be. Such evidence may be taken as an indication of the presence of the midge, even though the galls may not be numerous enough to attract attention.

From these data it is apparent that the insect is a serious pest, especially in cases where growers require from 50,000 to 100,000 plants for their own use and five to ten times this number to fill annual orders for shipment.

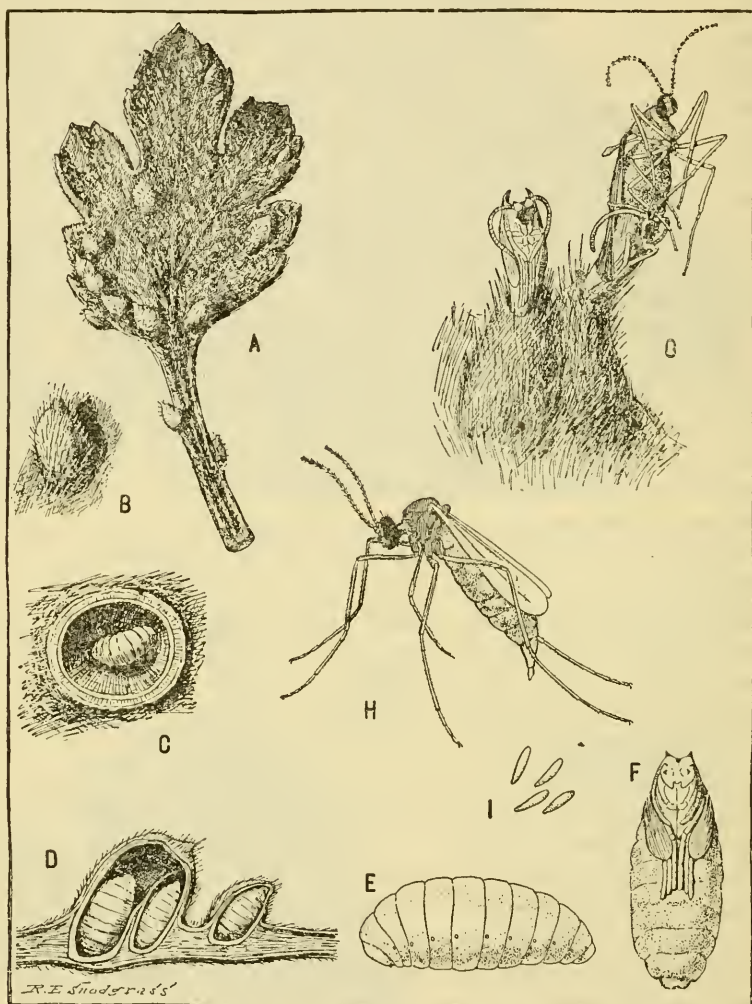


FIG. 2.—The chrysanthemum midge: *A*, Leaf covered with galls; *B*, a single gall, more enlarged; *C*, gall cut open from above, showing young larva within; *D*, two galls cut in vertical section; *E*, larva, enlarged about 13 times; *F*, pupa; *G*, fly emerging from a gall on right, discarded pupal skin remaining in opening of gall on left; *H*, adult female fly, enlarged about 13 times; *I*, eggs. (9th Ann. Rept. State Ent. Ind.)

TECHNICAL DESCRIPTION.¹

Egg [fig. 2, *I*].—Reddish orange, length .15 mm., diameter .03 mm., the extremities narrowly rounded.

Gall [fig. 2, *A*, *B*, *C*, *D*, *G*].—Conical swelling projecting obliquely from the surface. Size about 2 mm. in length. Color, generally green. Reddish green when growing outside and depending on variety affected. Tips appear dried out and grayish at

¹ Technical description of egg, larva, pupa, male, and female taken from Felt (20).

times. Hairs on tip in superabundance. Occurring on both leaf surfaces, stem and flower head.

Larva [fig. 2, C, E].—Length 1 mm., yellowish or yellowish orange when full grown, moderately stout, the extremities rounded; segmentation distinct and the skin smooth.

Pupa [fig. 2, F].—Length 1.25 mm., stout, narrowly oval, the cephalic horns distinct, conical, the thorax yellowish orange, the wing pads fuscous in pupæ nearly ready to transform, the leg cases dark yellowish brown, the abdomen a variable orange, narrowly rounded apically.

Male.—Length 1.75 mm. Antennæ nearly as long as the body, sparsely haired, fuscous yellowish; 17 or 18 segments, the fifth with a stem about three-fourths the length of the subcylindric basal enlargement, which latter has a length about twice its diameter and a rather thick subbasal whorl of long, stout setae; terminal segment variable, usually somewhat reduced, irregular, elongate, ovate. Palpi: The first segment subquadrate, the second narrowly oval. Mesonotum dark brown, the submedian lines yellowish. Scutellum and postscutellum fuscous yellowish, the abdomen mostly a pale yellowish orange. Wings hyaline, costa light straw, halteres yellowish transparent. Legs a pale straw, the pulvilli a little longer than the long, slender claws, the latter with a long, slender tooth basally. Genitalia; basal clasp segment moderately long, stout; terminal clasp segment short, stout, with a distinct spur; dorsal plate short deeply and roundly emarginate, the lobes short, broad, obliquely truncate apically; ventral plate short, deeply and roundly emarginate, the lobes rather long and tapering to a narrowly rounded apex.

Female [fig. 2, H].—Length 1.75 mm. Antennæ extending to the third abdominal segment, sparsely haired, fuscous yellowish; 16 or 17 segments, the fifth with a stem about one-third the length of the cylindric basal enlargement, which latter has a length a little over twice its diameter; terminal segment reduced, sometimes compound and tapering to a narrowly rounded apex. Palpi: The first segment subquadrate, the second subconical and with a length a little greater than the first. Mesonotum fuscous brown, the submedian lines, the posterior median area, the scutellum and postscutellum mostly fuscous yellowish, the apex of the scutellum narrowly fuscous. Abdomen reddish orange, apically fuscous yellowish, the ovipositor about one-half the length of the body; terminal lobes short, broad, broadly rounded and sparsely setose apically. Other characters practically as in the male.

LIFE HISTORY AND HABITS.

ADULT STAGE.

The adult female shows a marked preference to lay eggs in the buds, or in the tissues just unfolding from the buds. Serious injury to the host results from this habit, and the commercial value of the plant is greatly reduced, if not entirely eliminated.

Emergence of adult.—On March 26, 1919, H. L. Sanford observed the emergence of a female at 1.09 a. m. On the following night observations by C. A. Weigel taken at intervals varying from 15 to 20 minutes apart beginning at 12.30 a. m., and ending at 5.45 a. m., showed the emergences as follows: At 1 a. m., 1 female; at 4 a. m., 1 male; at 4.02 a. m., 4 females, 3 males. In addition the following observations were recorded: When the female emerges the body is pushed out of the gall for approximately three-fourths its length. The wings at this time appear as dark gray or black club-like appendages. The antennæ are moved about in a very active manner. The legs, which are at first folded parallel to the body, are thrust outward

and immediately begin movement. The body is swayed back and forth with contractions of the abdomen which is still inserted within the gall, the latter acting as a fulcrum. In about two minutes from the time at which the adult is first seen to break through the gall, the entire body is freed from its pupal skin. The pupal skin remains protruding from the empty gall case, as seen in Plate II, A. With a convulsive motion the insect gains a foothold by thrusting out the legs and was observed almost immediately to travel rapidly to the underside of the leaf, assuming a position at right angles to the leaf surface. In this hanging position, which is characteristic of the adult female, it remained over an hour, occasionally fluttering its wings. Upon being disturbed it made a very short flight and returned to the underside of the same leaf. Evidently the above-described position is assumed to allow for drying and inflation of the wings.

Mating.—A male was observed to fertilize a female approximately 3 minutes after the emergence of the latter, the entire operation taking 10 seconds. One male was observed to fertilize three females in rapid succession.

TABLE I.—*Longevity of adults and date of oviposition.*

Cage.	Adult emerged.	Number.		Oviposition.	Adults died.		Length of life.
		Male.	Female.		Male.	Female.	
	1917.						<i>Days.</i>
1	Apr. 2, a. m.	0	1	None.....		Apr. 5, a. m.	3
2	Apr. 5, a. m.	0	2	do.....		Apr. 8, a. m.	3
3	Apr. 6, a. m.	3	0	do.....	Apr. 6, p. m., 2		1
					Apr. 7, a. m., 1		1
4	Apr. 10, a. m.	2	2	Apr. 10.....	Apr. 10, p. m.		1
						Apr. 11, a. m.	1
5	do.....	2	2	None.....	Apr. 10, p. m.		1
						Apr. 12, a. m.	2
6	Apr. 11, a. m.	0	1	do.....		Apr. 13, p. m.	2
7	Apr. 12, a. m.	0	2	do.....		do.....	1
						Apr. 14, a. m.	2
8	Apr. 13, a. m.	3	1	Apr. 13.....	Apr. 13, p. m., 2		1
					Apr. 14, a. m.	Apr. 14, a. m.	1
9	do.....	1	1	do.....	Apr. 13, p. m.		1
						Apr. 14, a. m.	1
10	do.....	0	1	None.....		Apr. 17, a. m.	4
11	Apr. 17, a. m.	0	1	do.....		Apr. 20, a. m.	3
	1918.						
12	Jan. 31, a. m.	0	2	do.....		Feb. 1, a. m.	1
13	do.....	0	2	Jan. 31.....		Feb. 2, a. m.	2
14	do.....	0	1	do.....		Feb. 1, a. m.	1
15	do.....	1	2	do.....	Lost.....	Feb. 2, a. m.	2
16	Feb. 1, a. m.	0	2	Feb. 1.....		do.....	1
17	Feb. 11, a. m.	0	2	Feb. 11.....		Feb. 13, a. m.	2
18	Mar. 14, a. m.	1	0		Mar. 15, a. m.		1
19	July 10, a. m.	0	1	July 10.....		July 11, a. m.	1
20	July 17, a. m.	1	1		July 17, p. m.		1
						July 18, a. m.	1
21	July 18, a. m.	0	1			July 20, a. m.	2
22	July 19, a. m.	1	0		July 20, a. m.		1
23	Aug. 2, a. m.	2	0		Aug. 3, a. m.		1
24	Aug. 3, a. m.	0	1	Aug. 3.....		Aug. 3, a. m.	1
25	Aug. 5, a. m.	0	1	Aug. 5.....		Aug. 6, a. m.	1
26	Sept. 2, a. m.	1	0		Sept. 2, p. m.		1

¹ Female not fertilized and did not deposit eggs.

Longevity of adults.—In the life-history studies it was found that males usually live less than 12 hours, while the females live from 2 to 3 days, in captivity and when not mated. Mated females probably do not live over 24 hours. In the case of three males which were seen to emerge after 1 a. m., all were found dead at 5.45 a. m. These results are given in detail in Table I.

Activity.—The males are not often seen on the wing, as they die shortly after mating, which takes place during the early morning hours, almost directly after emergence. When on the wing, however, they are very active. The females, while generally rather sluggish, may show great activity at times, especially in the early morning and just prior to egg deposition. Dietz observed that on cool days when the temperature was 50° F. in the daytime, and cooler at night, the adult females were exceedingly active. Emergence records taken on many cages show that there are a somewhat larger number of females than males, the actual count being 464 females to 365 males.

Egg deposition.—The female when laying eggs keeps her legs at equal distances apart and the ovipositor held at right angles to the rest of the body, beginning probably at the third or fourth abdominal segment. If not disturbed she acts with great precision. On one occasion a female was carefully observed during two operations, laying 34 and 19 eggs respectively. The first oviposition period lasted exactly 3 minutes and 30 seconds, the second only 1 minute and 20 seconds. An interval of only 10 seconds elapsed between the operations. The tip of the long flexible ovipositor is thrust between the pubescent hairs of the young terminal growth and pressed down firmly on the surface. During deposition the eggs may be seen moving down the tube with great rapidity, accompanied by slight contractions of the ovipositor. Because of its darker color, the egg is plainly visible through the walls of the ovipositor. The number laid at one time, according to Table II on page 10, varies from 5 to 135, with an average of 32. Guyton (31) found that "the number deposited by each female is from 80 to 150." The eggs are usually placed in irregular masses, although they may be placed in strings or chains. During the whole operation the ovipositor is thrust around in a very nervous manner. At times when the female moves slightly about, the body is not straightened out but dragged along to the new place of deposition, in the original bent position. Although egg-laying may take place up to and later than 4.30 p. m., the maximum egg-laying occurs from the early morning hours up to midday. The midges prefer to lay eggs on the terminal growth of the plant on which they emerge, and particularly on the unfurling tip growth. This is true even in cases

where the terminal growth has been badly distorted previously as a result of their work. Females have been noted to return to such plants from which they have emerged and deposit eggs thereon. Even though they were repeatedly disturbed, they would return quickly and continue deposition. On many occasions it was found that when these young tips were separated and examined, the eggs would be present in greater numbers between the folds of the new tissue than on the neighboring exposed surfaces.

Incubation.—Observations, as given in Table II, show that the incubation period varies from 3 to 16 days. The time of incubation may be affected by the season of the year.

TABLE II.—*Length of egg period.*

Cage.	Host plant.	De- posited.	Hatched.	Length.	Number deposited.
		1917.		<i>Days.</i>	
1	October Frost.....	Apr. 2	Apr. 7.....	5	No records.
2	Snow Queen.....	Apr. 3	Apr. 8.....	5	Do.
3	Silver Wedding.....	Apr. 4	Apr. 9.....	5	Do.
4	Golden Glow.....	Apr. 5	Apr. 10.....	5	Do.
5	Harvard.....	Apr. 6	Apr. 11.....	5	Do.
6	Esanath.....	Apr. 7	Apr. 12.....	5	Do.
7	Snow Queen.....	Apr. 10	Apr. 15.....	5	Do.
8	Monrovia.....	Apr. 12	Apr. 17.....	5	Do.
9	Martha Saunders.....	Apr. 13	Apr. 18.....	5	Do.
10	Gold Chadwick.....	Apr. 16	Apr. 21.....	5	Do.
11	Esanath.....	Apr. 17	Apr. 22.....	5	Do.
12	Monrovia.....	Apr. 20	Apr. 25.....	5	Do.
		1918.			
13	Silver Wedding.....	Jan. 31 Feb. 1	Feb. 9.....	8-9	Do.
14	do.....	do.....	Feb. 7.....	6	Do.
15	do.....	Feb. 2	do.....	5	25 eggs.
16	Dr. Enguehard.....	Feb. 11	Feb. 15-19.....	4-8	No records.
17	Pompon.....	Feb. 28	Mar. 6.....	6	Do.
18	Silver Wedding.....	Mar. 1	Mar. 6-10.....	5-9	Do.
19	Dr. Enguehard.....	Mar. 4	Mar. 9.....	5	Do.
20	Dr. Pool.....	Aug. 26	Sept. 6.....	11	34 eggs.
21	Mrs. R. N. McLuckie.....	Aug. 27	Aug. 30.....	3	19 eggs.
22	Margaret Bissett.....	Aug. 29	Sept. 4-14.....	6-16	5 eggs.
23	Silver Wedding.....	do.....	Sept. 6.....	8	20 eggs.
24	Mensa.....	do.....	Sept. 6-14.....	8-16	24 eggs.
25	Silver Wedding.....	Sept. 5	Sept. 10-14.....	5-9	25 eggs.
26	Golden Wedding.....	Sept. 21	Sept. 24.....	3	135 eggs.

Development.—The development of the larva within the egg can be made out easily. In the newly laid egg the nucleus, which is reddish in color, is rather central, but shows a slight tendency to be located toward the anterior end. There are approximately 18 yolk bodies present which are arranged in a row of 9 on each side. The rows do not extend quite to the posterior end of the egg. As development proceeds the red pigment or nucleus moves to one side of the egg, which later is apparently the ventral surface. In the meantime the yolk bodies collect in a mass near the nucleus. At each end the small air spaces, which at first are relatively small, later become much increased in size. The segmentation then begins to appear, with a simultaneous contraction of the entire contents. A redistribution of

the yolk then takes place, an equal portion being present in each segment. At this stage the pigment takes up a posterior position. Finally the complete outline of the larva is visible through the shell. At this stage the darker head and mouth parts can be seen, and the previous yolk material appears as a chainlike formation which extends from the anterior to the posterior end throughout the entire inner or central portion of the body. Distinct segmentation is now clearly visible.

Hatching.—Borden observed the larva when hatching to break from the eggshell by a small cap at one end. Complete development of the larva and pupa takes place within the gall.

LARVAL AND PUPAL STAGES.

The larva or maggot upon hatching moves about on the surface among the plant hairs for a period of from 1 to 3 days, preparatory to boring into the tissue. It varies in color from a transparent white to pale orange when seen with the aid of a binocular just after boring beneath the epidermis. On February 2, 1918, H. F. Dietz observed larvæ, which hatched from eggs laid four days previously, boring into tissue. (10× eyepiece, 24 mm. objective, binocular.) The observations were as follows: One larva which was found half buried in the tissues of the stem was timed until it disappeared. It required 12 minutes for complete disappearance. During this period the larva moved back and forth with an irregular spiral movement, about 30 seconds being necessary for one complete movement back and forth. Several larvæ were then observed beginning to bury themselves, but the operation was interrupted and discontinued, the interruption being caused by another larva which was slowly crawling about in search of a suitable place to "dig in." One of these larvæ was observed crawling slowly about for approximately 3 minutes. The bright red pigment of the posterior third of the body is very characteristic at this particular stage.

As a result of the larva boring into the tissue, an irritation is produced which results in the production of swellings or galls on the plant containing the developing larvæ and pupæ.

No molts have been observed from the time of hatching to the time at which the larva is seen entering the tissue. The larva lies bathed in a fluid within the gall. The fully developed larva is of an orange color.

The female pupa is usually orange colored with the head, thorax, legs, and wing pads nearly black, while the male may be of a lighter or straw color. Formation of the pupa takes place about two weeks from the time the egg is hatched. It is white at first with only a slight brown tinge about the head, but later the head, thorax, wing-

pads, and legs are dark brown, and the abdomen orange. The cephalic horns are distinct in the nearly mature form of the pupa.

When mature the pupa works its way out of the gall. On emergence a split is made upon the dorsal line of the head and thorax of the pupal case through which the adult issues. (Pl. I, A, D.) During emergence the adult is very active and issues very rapidly.

From the time that the larva enters the tissue to the first sign of a swelling, or gall, observations on 18 life-history cages show that a period ranging from 4 to 14 days elapsed with an average of 7 days (see fourth column of Table III). The young gall may now be readily recognized by the characteristic white spots, or slight swellings.

It takes from 21 to 46 days, with an average of 28 days, from the time at which the larva first enters the tissue until the emergence of the adult. These observations were taken from the results obtained from 18 cages during the spring of 1917 and the spring and fall of 1918, as is shown in the following table. Britton (32) found it to require from 20 to 50 days to transform within the gall.

TABLE III.—*Time required from: (a) larva entering tissue until first sign of gall; (b) larva entering tissue until emergence of adult.*

Cage.	Larva entering tissue.	First sign of gall.	Time, required (a).	Date of emergence.	Total length (b).
			Days.		Days.
1	1917. Apr. 7-11.....			Apr. 29 to May 2.....	22
2	do.....			Apr. 30.....	21
3	do.....			May 1-2.....	23
4	do.....			Apr. 30 to May 2.....	22
5	1918. Feb. 7.....	Feb. 13-16.....	7	Mar. 4.....	25
6	do.....	do.....	7	Mar. 4-7.....	25
7	Mar. 6-12.....	Mar. 15.....	6	Apr. 6-22.....	36
8	Mar. 6-10.....	do.....	7	Apr. 8-22.....	38
9	Mar. 12.....	Mar. 18.....	6	Apr. 27.....	46
10	do.....	Mar. 16.....	14	do.....	46
11	do.....	Mar. 18.....	6	Apr. 6.....	25
12	do.....	do.....	6		
13	Aug. 31.....	Sept. 9-19.....	24	Sept. 25.....	25
14	Sept. 2.....	Sept. 9.....	7	Oct. 2.....	30
15	Sept. 4-14.....	Sept. 17.....	8	Sept. 26 to Oct. 3.....	21
16	Sept. 4-11.....	Sept. 11.....	7	Sept. 27 to Oct. 2.....	22
17	Sept. 7-14.....	Sept. 14-19.....	6	Oct. 4.....	23
18	Sept. 24-25.....	Oct. 2.....	8	Oct. 24 to Nov. 2.....	34

¹ Minimum time.

² Maximum time.

From Table IV it is evident that the total life cycle requires from 27 to 52 days, with an average of 35 days. These data represent the results obtained from 17 life-history cages under Washington conditions. There is a constant overlapping of broods when the greatest numbers are present, namely in the spring and fall of each year. The aestivation period has been found to extend, in Maryland, Virginia, and the District of Columbia, from the early part of June to the latter part of August.

TABLE IV.—Length of complete life cycle.

Cage.	Eggs deposited.	Adult emerged. ¹	Length of life cycle.
	1917.		Days.
1	Apr. 2.....	Apr. 29 to May 2.....	27-30
2	do.....	Apr. 30 to May 2.....	28-30
3	do.....	May 1 to May 2.....	29-30
	1918.		
4	Feb. 1.....	Mar. 4.....	31
5	Feb. 2.....	Mar. 4 to Mar. 7.....	30-33
6	Mar. 1.....	Apr. 8 to Apr. 22.....	38-52
7	Mar. 5.....	Apr. 6.....	32
8	Mar. 6-9.....	Apr. 22 to Apr. 27.....	47-49
9	Aug. 3.....	Sept. 4 to Sept. 6.....	32-34
10	do.....	Sept. 11 to Sept. 18.....	39-46
11	Aug. 6.....	Sept. 5.....	30
12	Aug. 27.....	Sept. 25 to Oct. 4.....	29-38
13	Aug. 29.....	Sept. 26 to Oct. 3.....	28-35
14	do.....	Sept. 27 to Oct. 2.....	29-34
15	do.....	Oct. 2.....	34
16	do.....	Oct. 4.....	36
17	Sept. 21.....	Oct. 24 to Nov. 2.....	33-42

¹ Data given in Table I show that mated females deposit eggs on date of emergence.

In the spring of 1917, 1918, and 1919, three distinct generations were observed. The first generation started about the middle of February and the last adults of this generation emerged during the last few days of April. The second generation started about the middle of March and the last adults issued around April 30. The third generation started the latter part of April and emerged during the early part of June. In the fall of 1918 when the occurrence increased again a similar grouping of generations was evident, the first beginning about the latter part of August, and the last adults emerging during the first days of October. A second generation started about the middle and latter part of September, maturing the first days of November. The third generation was observed beginning about the middle of October and the last adults emerged about November 25.

NATURAL ENEMIES.

Felt (20), in speaking of the natural enemies of the midge, states that—

It was very likely brought to America without the normal quota of parasites and for a time at least it may prove to be a somewhat difficult insect to control, though it would seem as if the native parasites of our large and varied gall midge fauna might in time prey most successfully upon this midge.

Essig (18) mentions:

During the summer a large number of parasites were reared from infested plants and one species in particular did excellent work in the university greenhouse. The material was sent away for determination and a few observations made as follows:

Amblymerus sp. This hymenopterous parasite has been described by Mr. A. A. Girault, through the kindness of Dr. L. O. Howard, and a description is to appear elsewhere. The adults are black with yellow markings on the legs. The females vary from 1 mm. to 1.2 mm. in length, and the males are somewhat smaller. The

larvæ live within the galls alongside the maggots of the gallfly, which they gradually consume. They remain within the galls until mature, when they emerge through small circular holes. This species is the most abundant during the summer months and all of the adults were reared during August, September, and October. In not a few cases as high as 80 per cent to 90 per cent of the maggots were destroyed.

Tetrastichus sp. The generic determination of this insect was made by Mr. Harry S. Smith, superintendent of the State insectary, Sacramento, Calif. It is also a small black parasite, somewhat larger than the former and easily distinguished from it by the four-jointed tarsi and other characters.

EXPERIMENTS IN CONTROL.

At the outset it must be borne in mind that it is very important that control measures should be closely related to the propagation of the stock, and moreover from the practical and economical point of view these steps should be undertaken at a period in the propagation when the plants can be severely cut back, allowing sufficient time to overcome any injury which may result from such treatment. Inasmuch as cuttings are propagated from the stock plants of the previous season, it is evident that the logical time to eradicate an infestation of long standing is immediately after the flowers have been removed. Naturally such precautions as would absolutely safeguard the grower against further spread and increase would have to be inaugurated.

An experiment conducted in one of the commercial greenhouses in the District of Columbia in which the plants had been heavily infested the previous season was carried out as follows: These heavily infested stock plants were heeled in and pruned back, and the entire portion above ground was thoroughly dusted with a mixture of equal parts of tobacco dust and air-slaked lime as often as the new growth appeared. As a result of such treatment the new growth was kept practically clean from further infestation and the plants at the same time showed a stimulated growth. The checks which were run simultaneously had all the new growth badly infested.

Occasionally it may happen that a grower's previous season's stock was clean and new material or varieties are being received in the form of cuttings or young plants from localities where the insect is known to exist. There is a possibility of introducing the midge on such stock even though no definite signs of the insect are visible. In the spring when cuttings and young plants are being exchanged, an infestation, especially in the egg or very young larval stage, will defy even the most careful and zealous inspectors. Interception made of plants harboring the eggs only can easily be overlooked by virtue of their concealed location in the still unfurled leaf bud.

A precautionary treatment should be given at the time when the plants or cuttings are taken or received and would prove of inestimable value in killing the eggs and immature stages.

The question of controlling an infestation already in the well-developed gall stage as well as the adult stage must also be con-

sidered. The control of the adult stage need not be taken up in experimental manner, in view of the known fact that such fragile flies can easily be controlled by light fumigation with hydrocyanic-acid gas or by burning tobacco papers, provided it is done at the correct time.

The preceding paragraphs clearly point out the advisability of determining the practical value of the several premises stated. Incidentally such factors must necessarily be solved independently of each other, but with the final view of either applying each separately when the case so warrants or consolidating such phases as would be most practical and consistent with commercial practices. The practical conclusions and recommendations that follow were deduced from results that are outlined and stated in the following pages.

EXPERIMENT 1.—CONTROL OF EGGS BY MEANS OF DIPPING INFESTED CUTTINGS.

Emphasis has been placed on the importance of beginning with clean cuttings in the spring. It, therefore, was found advisable to test out this point, and, if effective, such practices would be a safeguard to growers whose stock was badly infested as well as growers who had received outside material.

Three lots of six cuttings each were treated by J. L. Dietz as given in the following table. After treatment they were planted in sand. The tray, together with the plants, was then protected from further attacks by placing it under a close-mesh screen. The plants were treated September 26, and observations taken October 5 and 10 and November 1 are given in Table V.

TABLE V.—*Control of eggs by means of dipping infested cuttings.*

Experiment.	Treatment.	Observations and results.
1	40 per cent nicotine sulphate (1-500); laundry soap 1 ounce to 1 gallon; tips of cuttings dipped. Sept. 26, 1918.	Nov. 1: Eggs did not hatch; no new galls developed; 4 plants well rooted, 2 plants poorly rooted.
2	Same treatment as above, except that entire cuttings were dipped. Sept 26, 1918.	Nov. 1: Eggs did not hatch; no new galls developed, neither did original galls develop any further; 4 plants well rooted, 2 plants poorly rooted.
3	Check; no treatment	Nov. 1: Eggs hatched; 1 plant had 3 well-developed galls present; 3 plants rotted off; 3 plants were well rooted.

DISCUSSION OF RESULTS.

Comparing the results of both treated lots with those of the check, the results are fairly conclusive. On the treated plants the eggs in each case did not hatch, neither did the young galls originally present make further progress, whereas, in the case of the check, while only one plant showed definite results, it is clear that the galls developed.

The effect of such treatment on the plants is somewhat inconclusive due to the rotting off of three plants in the check. In the case of the treated plants, four survived in each lot.

EXPERIMENT 2.—CONTROL OF EGGS BY MEANS OF DIPPING ENTIRE PLANT.

The object of this experiment was practically synonymous with that of experiment 1 except that entire plants were used instead of cuttings as was the case in the previous test.

Twelve plants on which newly laid eggs were present were divided into three lots, (a), (b), and (c), of four plants each. They were then treated as follows:

- (a) Four plants dipped in 40 per cent nicotine sulphate (1-500) plus laundry soap 1 ounce to 1 gallon of solution.
- (b) Four plants dipped in 40 per cent nicotine sulphate (1-800) plus laundry soap 1 ounce to 1 gallon of solution.
- (c) Four plants as check; no treatment.

In each case the plants were constantly protected by covering them with an ordinary lantern globe, the free end of which was screened with a double layer of cheesecloth. The first dipping was done on March 29, while subsequent dippings were done on March 31 and April 1, 3, and 8. The plan was to treat them at least every 2 or 3 days for a week or 10 days. Observations were taken frequently on the effect of the treatment both on the plants and on the eggs. These observations were continued until the close of the experiment, April 30, at which time the plants were uncovered and placed in the open greenhouse.

Results.—(a) Effect on plants: Slight burning was encountered with the 1-500 strength solution, but with the 1-800 solution no such trouble was evident. The check plants showed some sooty fungus which was probably due to the presence of honeydew secreted by aphids. (b) Effect on eggs: During the first few days the eggs showed normal development within the shell on the treated plants, but larvæ failed to hatch from them, and no galls developed. On the check plants all of the eggs hatched successfully and many galls developed to maturity.

Conclusions.—The expectations were fully confirmed by the results obtained, as was the case in experiment 1. The checks developed healthy and normal galls while in the treated plants further development was promptly arrested. From the economical point of view it is safe to say that nicotine sulphate (1-800) plus the soap will control the egg stage effectively if properly applied.

TREATMENT OF BOTH CLEAN AND INFESTED CUTTINGS.

The importance of having all new stock free and clean from the immature stages of the midge and of having the control at all times closely related to the propagation of stock has already been referred to. The above points were tested by the following experiment.

This test consisted of three parts. Lots 1 and 2 were clean cuttings, while lot 3 consisted of infested cuttings. Each lot was sub-

divided into three divisions or rows, namely, (a), (b), and (c). The last, (c), in each case served as a check on (a) and (b), which were the treated rows. The first treatment consisted of dipping the cuttings directly after they were taken, and the subsequent treatments consisted in spraying daily for a period of 7 days thereafter with a solution of the same strength.

Lot 1 consisting of clean cuttings to be used as a check was kept in a separate and uninfested unit for the purpose of determining the effect of such treatment on the cuttings. Lot 2 consisting of clean cuttings and lot 3 of infested cuttings were both tightly screened and placed in a propagating frame in an infested unit. In this manner it was hoped to determine the effectiveness of such treatment when both clean and infested cuttings had to be grown together.

LOT 1.

Six clean cuttings in each row.

Row (a). Nicotine sulphate (1-800) plus fish-oil soap 1 ounce to 1 gallon of solution.

Row (b). Volatile nicotine sulphate (1-800) plus fish-oil soap 1 ounce to 1 gallon of solution.

Row (c). Checks; not treated.

Results.—During the period of treatment it appeared as though all the plants were affected slightly. Row (a): The lower leaves of all the cuttings turned yellow, but 10 days after treatment was discontinued all but one cutting were in fine condition. Row (b): Even though no direct signs of burning were evident, the plants appeared sickly during the second and third treatments. Ten days after the discontinuance of the treatments the cuttings were in better condition than either (a) or (c). The check row (c) was slightly affected due to its proximity to the treated rows. Ten days after treatment was stopped only two plants were in good condition and one was poor.

The conclusion to be drawn from this test is that the method of treatment under (b) was probably the better of the two.

LOT 2.

Seven clean cuttings in each row. Placed in infested unit after first treatment.

Row (a). Nicotine sulphate 40 per cent (1-1,000) plus fish-oil soap 1 ounce to 1 gallon of solution.

Row (b). Volatile nicotine sulphate 40 per cent (1-1,000) plus fish-oil soap 1 ounce to 1 gallon of solution.

Row (c). Checks; no treatment.

Results.—Although this dosage was weaker than that used in lot 1, it affected the cuttings much more. After the second and third treatments the plants all looked wilted. Ten days after the last

application all the cuttings but one in row (a) were dead. In row (b) all looked very poorly. In (c), the check row, one cutting was dead while all the remainder looked fairly healthy.

Conclusions.—It appears that the variety may have played an important part in this case. In this lot, as was so evident in the previous treatment, (a) causes injury, while (b) gives a double benefit—first, it does not cause injury; and second, it protects the plant. The midges spread to the check row (c), and two galls had adults emerge from them.

LOT 3.

Three rows of seven infested cuttings each.

Row (a). Nicotine sulphate 40 per cent (1-1,000) plus fish-oil soap 1 ounce to 1 gallon of solution.

Row (b). Volatile nicotine sulphate 40 per cent (1-1,000) plus fish-oil soap 1 ounce to 1 gallon of solution.

Row (c). Check; not treated.

Results.—This variety stood up much better than did that in lot 2.

Row (a). Slight burning evident. In fair condition 10 days after treatment.

Row (b). Only two poor plants; no burning. All recovered 10 days after treatment.

Row (c). All plants in good condition, slightly better than row (b). No galls developed.

Either treatment (a) or (b) might be used successfully.

FINAL CONCLUSIONS.

Comparing the three lots with one another the following conclusions may be drawn: The practices described injure the cuttings only slightly and afford reasonable protection from the midges.

EXPERIMENTS ON CONTROL OF GALL STAGE.

The final consideration concerns the control of the gall stage, which is the hardest to combat. Owing to the habit of the larvæ of burrowing into the plant tissues, the chief difficulty is that most spraying mixtures when applied to foliage fail to exert their toxic properties against the insects contained therein. This may be accounted for by the resistance of the leaf structures to penetration by insecticides.

EXPERIMENT 1.

A preliminary experiment, in which was used 1 part 40 per cent nicotine sulphate to 250, 500, and 1,000 parts water, respectively, to which fish-oil soap or laundry soap at rate of 1 ounce to each gallon of solution was added, showed conclusively that one application was entirely ineffective in controlling the gall stage. The data which were taken at various intervals showed that the adults emerged

successfully and continually. Hence, it was decided to test out the efficiency of several applications when made two and three days apart. The test is given in the next paragraph.

EXPERIMENT 2.

In the treated lots five plants were used for (a), (b), (e), and (f), and six plants for (c) and (d) for each test. The plants used had been growing in pots. Only two plants were used in both checks. The dipping was done as indicated every two or three days. Observations were taken daily.

TABLE VI.—*Results of experiment 2.*

Started.	Closed.	Treatment.	Total emerged.	Total killed.	Percentage of efficiency.	Remarks and conclusions.
1919.						
(a) May 1...	May 10..	Nicotine sulphate (1-500), fish-oil soap 1 ounce to 1 gallon.	217	123	56.6	Greatest efficiency within 24 hours of treatment.
(b) May 1...	May 10..	Nicotine sulphate (1-800), fish-oil soap 1 ounce to 1 gallon.	152	86	56.5	Same as above.
(c) May 19..	May 23..	Nicotine sulphate (1-1,000), fish-oil soap 1 ounce to 1 gallon.	45	30	66.6	Lower leaves turned yellow and died on most plants.
(d) May 19..	May 23..	Volatile nicotine sulphate (1-1,000), fish-oil soap 1 ounce to 1 gallon.	72	35	48.6	Slight blackening of tips on larger leaves.
(e) May 1...	May 10..	Linseed-oil emulsion plus nicotine sulphate (1-800).	80	2	2.5	Not efficient.
(f) May 7....	May 9...	Fish-oil soap 1 ounce to 1 gallon.	Many.	0	0	All emerged successfully; not efficient.
(g) May 1...	May 10..	Check.....	Many.	0	0	All emerged successfully.
(h) May 19..	May 23..	Check.....	Many.	0	0	Same as above.

Discussion of results.—The data represented in Table VI are self-explanatory as to the relative value of the various strengths and combinations of insecticides. The mathematical representation of the first two lots does not clearly define the actual state of affairs. It was repeatedly observed that on the day following treatment the number of adults killed was usually larger than on the second or third day. In other words, the effectiveness of such practices depends entirely on the interval which elapses between applications, and the conclusion to be drawn is that nightly or daily applications are absolutely necessary to get the maximum killing. The insecticide proved to be effective in killing the adult in the act of emergence, but did not sufficiently penetrate the tissues of the leaves to kill the immature stages within the galls. The column "Total killed" is understood to mean the killing of the adult in the process of emergence (Pl. II, B). It is also important that the treatment should be applied when the adults are almost ready to emerge from the galls.

EXPERIMENT 3.

In the foregoing experiment it will be observed that good results were obtained with the nicotine sulphate diluted to 1-800. Another point upon which it seemed desirable to have more definite information was the effectiveness of applications made daily compared with those made two days apart. In the following experiment two lots were treated, while the third lot served as a check. The empty galls were punctured and all old pupal skins were removed from the plants in question. Eighteen plants were employed in each of the two treated lots, which were sprayed a total of five times. Five plants served as a check.

TABLE VII.—*Results on first and second days after treatment.*

Lot.	Treatment.	Results first day after treatment.				Results second day after treatment.			
		Males.	Fe-males.	Total killed.	Pupal skins.	Males.	Fe-males.	Total killed.	Pupal skins.
1	Nicotine sulphate 40 per cent (1-800) and soap.....	38	43	81	15	1	1	2	16
2	Volatile nicotine sulphate 40 per cent (1-800) and soap.....	18	18	36	22	1	2	3	23
3	Checks.....	0	2	2	74	.....	.....	.....	.....

Conclusions.—The results are very conclusive and show distinctly that the best results are obtained by daily application. There is a remarkable decrease in the numbers caught on the second day following treatment. Nicotine sulphate, therefore, used at the rate of 1-800 plus soap (1 ounce to 1 gallon) will control the adult on emergence, and hence is very well adapted to such cases where fumigation can not be followed consistently.

EXPERIMENTAL WORK IN COMMERCIAL CHRYSANTHEMUM GREENHOUSES.

Experimental work in a commercial greenhouse in Baltimore during the summer of 1918 seems to indicate that the chrysanthemum midge can be held well under control by spraying the infested plants with 40 per cent nicotine sulphate applied at the rate of 1 part of nicotine sulphate to 500 parts of water, with the addition of one-half ounce of soap to each gallon of solution. No appreciable injury followed the application, although the plants were sprayed every other day for a period of six weeks. The application of this treatment by the grower resulted in his producing especially fine chrysanthemums. It would appear that a double benefit was realized by such practices. In the first place it controlled the insect, and, secondly, a distinct stimulation of growth followed. This seems to confirm the work of Gossard (30) and Guyton (31), who claim that 40 per cent nicotine sulphate diluted with 500 parts of water and

fish-oil soap will kill the adult almost immediately after emergence, if the spray is applied not more than three or four days previously.

A separate sash house was erected closely adjoining the greenhouse in which the spraying was done. Here 100 plants were fumigated nightly for approximately eight weeks, tobacco paper at the rate of 1 sheet to every 650 cubic feet of space being used. While some burning resulted, the midge was held in check. From these two experiments it is evident that either practice would be efficient.

A large commercial grower in Indiana reports that following instructions of this bureau he entirely eliminated the midge from his houses by fumigating with tobacco papers every night from December 20, 1917, to March 20, 1918.

Experiments conducted in several greenhouses in the District of Columbia in 1919 have indicated that consistent nightly fumigation is very effective in keeping down this insect. In several places where this was not advisable an effective spray was applied, consisting of nicotine sulphate (1-800) plus soap (one-half ounce to 1 ounce to each gallon of solution).

SUMMARY OF CONTROL AND RECOMMENDATIONS.

From the life history, as well as from the experimental data thus far submitted, it is clear that certain points must be kept in mind if the best practical results are to be secured. First, several generations are always present in greenhouses during the spring and fall occurrences; second, the adults emerge and mate during the very early morning hours, and egg laying quickly follows; third, preliminary control experiments show that the egg stage may be controlled by means of spraying or dipping the cuttings or plants; fourth, it has been demonstrated that the adult can be killed easily at the time of emergence by consistent spraying; fifth, fumigation experiments in a commercial house proved that the adult is easily killed by fumigation either with nicotine papers or hydrocyanic-acid gas; sixth, experiments applicable to general propagation practices show conclusively that such measures offer a reasonable safeguard and protection against doubtful stock and infested material without injury to the plants.

By adherence to a definite control program, involving any of the above cited measures, either singly or in combination, the insect can be readily controlled.

In case of a very light infestation daily picking of gall-infested leaves will hold the pest in check. Should this practice prove ineffective, nightly fumigation for a period of two or three weeks may be resorted to.

When a severe infestation is encountered the most heavily infested plants should be taken out immediately and burned.

This should then be followed by either fumigation or spraying as outlined below.

Fumigate every night, with either nicotine papers or hydrocyanic-acid gas, for a period of at least six weeks. This will kill all the adults that emerge during such a period and at the same time will prevent the further laying of eggs for future generations. The dosage need not be very heavy in either case. When nicotine papers are used one sheet to every 1,000 cubic feet of space will suffice. If hydrocyanic-acid gas¹ is employed, one-eighth to one-fourth ounce per 1,000 cubic feet will kill all of the adults. The use of hydrocyanic-acid gas is not recommended unless in the hands of a competent fumigator, owing to its deadly poisonous effects. Too much emphasis can not be laid on the fact that the fumigation must be set off after 12 o'clock, midnight, to be effective. It is preferable to start the generation between the hours of 12.30 a. m. and 2 a. m. Any fumigation done before midnight would be useless for it has been pointed out that the adult does not emerge until after midnight. On the other hand, if it is started later than 2 a. m. many adults will have emerged and laid their eggs.

In case fumigation is not advisable, especially where chrysanthemum plants are isolated or when other varieties of plants are present in the houses, spraying is recommended. This must be done consistently for a period of four to six weeks, a 40 per cent solution of nicotine sulphate extract diluted (1-800) being used, and soap added at the rate of one-half to 1 ounce per gallon of solution. The application should be made late in the afternoon in order that the best results may be obtained. In this manner practically all adults can be killed at the time of emergence and any eggs present will be destroyed.

PREVENTIVE MEASURES.

It has been proved that the means of disseminating this insect has been the shipment of infested chrysanthemums, both plants and cuttings. Interceptions made by the various State inspection officials, as well as by inspectors of the Federal Horticultural Board, definitely confirm this fact. It is therefore imperative that only clean plants and cuttings be brought into commercial houses where chrysanthemums are growing or to be grown. Growers should carefully examine all chrysanthemums received and see that all material intended for shipment or distribution is free from this pest. Any questionable material should at once be submitted to the State

¹ For further information on the use of hydrocyanic-acid as in fumigating greenhouses, see Farmers' Bulletin 880.

experiment station or to the Bureau of Entomology, United States Department of Agriculture.

The California Experiment Station (18) recommends the practice of growing the bulk of the chrysanthemum crop under cloth as a satisfactory means of preventing the attack of the gall-fly.

As a further preventive measure, it is recommended that cuttings be dipped in the following solution at the time they are taken:

Nicotine sulphate, 40 per cent.....	part..	1
Water.....	parts..	800
Laundry soap.....	ounce per gallon..	$\frac{1}{2}$ -1

Another satisfactory method of securing chrysanthemum cuttings free from the midge when the previous season's stock has been infested is to plant the stocks in benches or cold frames directly after the season's crop has been removed. This should then be followed by thorough treatment with a mixture consisting of equal parts of dry or air-slaked lime and tobacco dust. It is advisable to keep all new growth covered with the mixture until further operations in the spring.

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BULLETIN No. 834

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief



Washington, D. C.

PROFESSIONAL PAPER

May 19, 1920

BLACK GRAIN-STEM SAWFLY OF EUROPE¹ IN THE UNITED STATES.

By A. B. GAHAN, *Entomological Assistant, Cereal and Forage Insect Investigations.*

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INTRODUCTION.

That another exotic insect with possibilities for damage to agriculture has become established in America, that it is now quite widely distributed, and that it has already begun to make itself felt was brought to light during the summer of 1918. In view of its probable future importance and the consequent desirability of learning as soon as possible the facts about its distribution, food plants, and injuriousness, it is deemed expedient to bring the matter to the notice of entomologists and others through publication at this time of such information as is at hand.²

¹ *Trachelus tabidus* (Fab.).

² The writer is indebted to Miss Margaret Fagan, of the Bureau of Entomology, for compilation of the appended bibliography; to Messrs. W. R. McConnell, P. R. Myers, and W. J. Phillips, also of the Bureau of Entomology, for reared and collected material and notes which were invaluable in establishing the identity and distribution of the insect; to Dr. J. Chester Bradley, of Cornell University, for larval material of *Cephus pygmaeus* as well as useful suggestions regarding characters for separating the larvæ; and to Messrs. S. A. Rohwer and Wm. Middleton for numerous helpful suggestions.

HISTORY OF DISCOVERY OF THE INSECT IN AMERICA

Specimens of a sawfly were collected by C. W. Johnson at River-ton, N. J., some time prior to 1899, the exact date unknown. These were submitted to Dr. W. H. Ashmead for determination and pronounced by him a new species, to which he gave the manuscript name of *Calameuta johnsoni*. Under this name, misspelled *Calamenta johnsoni*, the record was published, without description, in the second edition of Insects of New Jersey, by John B. Smith (39).¹ A description based on these specimens was later published by Ashmead (40). Subsequently the type specimens were examined by Dr. J. Chester Bradley, who recognized in them the European species *Trachelus tabidus* Fabricius, and under this corrected name the record of the original collection was again published in the third edition of Insects of New Jersey (45). At that time, and for some time thereafter, nothing was known of the food plants of the species in this country. Such European records as existed were in the Russian literature, and because of difficulty in translation were largely overlooked. Since *Trachelus tabidus* was not known to be causing any injury, no particular attention was paid to it.

During the summer of 1918 a complaint was received by the Bureau of Entomology from a correspondent at Gaithersburg, Md., regarding the work of some insect which had caused his ripening wheat to fall badly, and the writer was detailed by Mr. W. R. Walton, in charge of Cereal and Forage Crop Insect Investigations, to investigate the outbreak.

Specimens of the injured stalks were received from the correspondent, some of which proved to contain larvæ of what was readily determined as a species of Cephidae. The insect was at first thought to be either *Cephus pygmaeus* Linnaeus or *Cephus cinctus* Norton. The former species had been known in the vicinity of Ithaca, N. Y., many years before, but so far as the records indicated, had succeeded in spreading but little from the point of original infestation and had never been recorded as seriously injurious. *Cephus cinctus* was known only from the western United States and was not believed to occur east of the Mississippi River except for a few localities in Michigan.

When the Maryland infestation was brought to the attention of Mr. S. A. Rohwer, specialist on sawflies, of the United States Department of Agriculture, Bureau of Entomology, he at once suggested the possibility that the insect might be *Trachelus tabidus* Fabricius. Several adult specimens of this species in addition to those originally taken at River-ton, N. J., were in the United States National Museum. These, as shown by the labeling, were collected at two or three differ-

¹ Numbers in parenthesis refer to "Literature cited," p. 14.

ent points in Maryland and Pennsylvania. The fact that *Trachelus tabidus* was thus known to occur in the region of the infestation and that it was the only species of Cephidae known to occur there which would be likely to have the habit attributed to this one, at once established a strong probability that it was the species concerned. This suspicion was confirmed when Messrs. W. R. McConnell and P. R. Myers, who had been engaged for several years in investigating the insect enemies of wheat and other cereals for the Bureau of Entomology in Maryland and Pennsylvania, turned over to the writer all of the sawfly material which they had secured from that region. This material all proved to be *Trachelus tabidus* and included several specimens which had actually been reared from wheat stubble in breeding cages, as well as numerous specimens collected by sweeping wheat. The reared material left little doubt as to the identity of the depredator in question. Reference to the European literature, especially that by a number of the more recent Russian entomologists, regarding *Trachelus tabidus*, cleared up whatever lingering doubts might still have existed.

The manner in which this insect became established in America is unknown and probably will remain a mystery. Any surmise as to the probable manner of introduction would be valueless and since it could have no effect upon the fact that it probably has come to remain, is omitted.

COMMON NAME OF THE SPECIES.

In Russian literature this species is referred to as the black sawyer or black sawfly because of its nearly uniform black color. The writer has ventured to modify this name to some extent by calling it the black grain-stem sawfly. This name is descriptive of the insect as well as of its habit and at the same time minimizes the possibility of confusion with other black species of sawfly.

DISTRIBUTION.

OLD-WORLD DISTRIBUTION.

André (33) records the species as occurring in England, France, Sweden, Spain, Germany, Italy, Algeria, and Syria. Cameron (35) in his "Monograph of the British Phytophagous Hymenoptera" gives practically the same distribution, omitting France. Konow (42) in *Genera Insectorum* cites middle and southern Europe, Algeria, and Asia Minor. Several writers, including Shtchegolev (49), Kurdjumov (48), Uvarov (50, 54), Zolotarevsky (53), and Borodin (52), have recorded it more recently from central and southern Russia, while Kulagin (47) states that *Cephus pygmaeus* and *Trachelus tabidus* have been recorded from 26 different governments of Russia.

From this it will be seen that the species occurs in all three Old World continents, being present throughout most of the middle and southern European countries, southeastern Asia, and northern Africa. It is probable that it will eventually be found to be present throughout most of the remaining regions where wheat is grown in Europe and eastern Asia, as well as northern Africa.

DISTRIBUTION IN AMERICA.

The present distribution in America, gleaned from the writer's investigations, the records of Messrs. McConnell and Myers, which were kindly placed at his disposal, specimens in the United States National Museum, and a note furnished by Dr. J. Chester Bradley, includes localities in six States, viz: New Jersey, Virginia, Delaware, Maryland, Pennsylvania, and New York.

The localities where the insect is at present known to occur, together with the date of collection and the name of collector, are as follows:

Riverton, N. J., adults collected by C. W. Johnson, May 29 (year not given but prior to 1899); East Falls Church, Va., hibernating larvæ in wheat and rye stubble, A. B. Gahan and S. A. Rohwer, collectors, August 6, 1918; Warrenton, Va., larvæ collected in August, 1918, by W. J. Phillips; Harrington, Del., larvæ collected in wheat stubble by W. R. McConnell; Wolfsville, Md., adults swept in clover field by J. A. Hyslop, June 6, 1914; Hagerstown, Md., adults swept from wheat by P. R. Myers and W. R. McConnell, May 15, May 25, June 4, 1915, and May 24 and June 8, 1916; Hagerstown, Md., adults reared from wheat stubble by P. R. Myers, May 10, 1916, and by W. R. McConnell, May 3, 1917; Taylors Island, Md., adult reared from wheat stubble by W. R. McConnell, March 21, 1917; Great Falls, Md., adult swept by Frederick Knab, May 24, 1914; Germantown, Md., larvæ injuring wheat received from a correspondent by the Maryland State College of Agriculture, and recorded under the name of *Cephus pygmaeus* in Report of Maryland State Horticultural Society, 1914; Gaithersburg and Laytonsville, Md., hibernating larvæ collected by A. B. Gahan in wheat stubble, July 22, 1918; College Park, Md., hibernating larvæ in wheat by A. B. Gahan, July 24, 1918; Berwyn, Md., hibernating larvæ in rye stubble collected by A. B. Gahan, July 30, 1918; Laurel, Md., hibernating larvæ in wheat stubble, by A. B. Gahan, July 26, 1918; Towson, Md., hibernating larvæ in wheat stubble, by A. B. Gahan, August 2, 1918; Warfordsburg, Pa., adult reared from wheat stubble by P. R. Myers, June 5, 1916; Hunters Run, Pa., adult reared from wheat stubble, W. R. McConnell, May 7, 1918; West Chester, Pa., adult collected by H. L. Parker, June, 1915; Linglestown, Pa., adults collected by H. B. Kirk and A. B. Champlain, May 26, 1908; Herndon, Pa., adults, collector unknown, June 6, 1907; State College, Pa., adult swept in clover by W. R. McConnell, May 30, 1911; Carlisle, Pa., larvæ collected July 23, 1918, by C. C. Hill, and July 31, 1918, by W. R. McConnell; Mt. Holly Springs, Pa., larvæ collected in wheat stubble, June 25, 1918, by McConnell and Myers.

In addition to these records Dr. J. C. Bradley states that he has seen one adult specimen in the collection of the Brooklyn Museum from Long Island, N. Y.

These records probably indicate only approximately the present distribution (fig. 1) of the species. A more extended investigation will be necessary to establish the exact limits. The records are sufficient to establish a probability that it already occurs over the greater part of Virginia, Maryland, Pennsylvania, New Jersey, and Delaware, and it is possible that West Virginia, eastern Ohio, southern New York, and even some of the New England States may already be included within its range.

PROBABLE FUTURE DISTRIBUTION IN AMERICA.

Judging by its wide distribution in the Old World, as well as by the character of localities already included within its range in this country, including both tidewater and mountain districts, there seems little reason to doubt that the species will eventually spread over all the wheat-growing sections of the eastern and central United States. Whether it will accommodate itself to the arid and semiarid wheat-growing districts of the West is matter for speculation. The average precipitation of this region does not differ greatly from that of southern

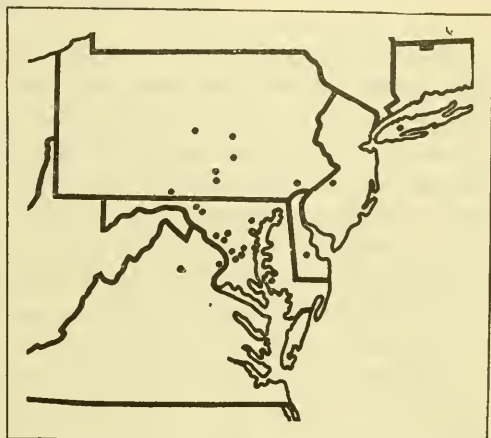


FIG. 1.—Present known distribution of *Trachelus tabidus* in America.

Russia, where the species seems to be at its worst. The mean temperatures of the two regions probably are not widely different. It seems possible, therefore, that unless some other climatic or physical factor intervenes, the species may spread eventually from coast to coast. That it will spread northward into Canada may be doubted, since in Europe, although recorded from Sweden, it seems not to occur generally in the colder northern portion.

FOOD PLANTS.

FOOD PLANTS IN EUROPE.

In European literature, with one exception, the records of food plants of *Trachelus tabidus* are by Russian entomologists. Rudow (43), in speaking of *Cephus satyrus* Panzer, *C. nigrinus* Thomson, *C. pallipes* Klug, *C. arundinis* Giraud, and *C. tabidus* Fabricius, makes the general statement that in southern Europe these species live in

Triticum repens, *Bromus*, *Holcus*, and reeds or bulrushes, without specifying which plants serve as host plants for the different species. The record is, therefore, too general to be of much value in the present circumstances.

The Russian records are more specific and apparently all refer to infestation of small-grain crops. Shtchegolev (49) records the species as a serious pest of wheat; Borodin (52) reared it together with *Cephus pygmaeus* from barley and both spring sown and winter sown wheat; Kulagin (47) states that it infests rye and wheat in the Province of Taurida. Various other Russian writers, including Uvarov (50) (54), Zolotarevsky (53), and Kurdjumov (48), have recorded the species as attacking the grain crops, principally wheat.

FOOD PLANTS IN AMERICA.

Thus far in America only wheat and rye are known to serve as food plants. Only two instances of its occurrence in rye are known, both observations having been made by the writer during the past summer. In each instance in which it was found in rye only one infested stalk was located in the field, although careful search was made. Although several fields of oats stubble were examined more or less carefully, no infestation of this crop was observed even when the oats were in close proximity to infested wheat fields. No opportunity to examine barley has offered itself.

It appears fairly certain that of the cultivated grain crops wheat will prove to be its preferred food plant. As stated elsewhere, the writer was able to find larvæ in varying quantities in every wheat field visited in the course of the limited investigation carried on during the summer of 1918.

That the species eventually will be found to infest plants other than the small grains is possible. The related species, *Cephus cinctus*, which also infests the small-grain crops in our Western States, is known to have a long list of food plants among the coarser grasses, both wild and cultivated. *Cephus cinctus* is believed, however, to be a native species whose original food plants were wild grasses and whose habit of attacking the cultivated grains has been induced through elimination or reduction of its natural source of food supply by the development of agriculture. Present information indicates that the natural food plants of *Trachelus tabidus* are the small grains, although it may yet prove to have other hosts in Europe. It is doubtful whether the species which has been transplanted from its native habitat to America will find it possible to develop in our native grasses. Only future investigation can determine. The possibility of its being able to maintain itself upon grasses other than the small grains should be borne in mind, and

such grasses as *Elymus*, *Bromus*, *Agropyron*, and in fact any of the cultivated or wild grasses whose seasonal development is such as to provide a succulent stem of sufficient size to accommodate the larvæ during the period of larval activity, May and June, should be viewed with suspicion.

SYNONYMY AND DESCRIPTION OF *TRACHELUS TABIDUS*.

Since the original description by Fabricius (1), the name has undergone a number of generic transfers, and it has been redescribed or referred to under several specific names.

It is the opinion of the writer, however, that some of the published synonymy is incorrect. *Trachelus haemorrhoidalis* Jurine (17) is listed as a synonym by Dalla Torre (38). The figure given by Jurine is not that of *tabidus*, but is undoubtedly identical with *Cephus analis* Klug (12). The latter name is generally recognized by European writers as a synonym of *haemorrhoidalis* Fabricius (2). Konow (41) includes *Sirex macilentus* Fabricius (9), *Cephus erberi* Damianitsch (30), and *Cephus vittatus* Costa (32) as color varieties of *tabidus*. The large number of specimens of *tabidus* examined by the writer show no variation in color comparable to *macilentus* as illustrated by Coquebert (10), and since other European writers generally have recognized this as a distinct species it has been excluded from the synonymy. *Cephus erberi* is described as having the third to seventh dorsal abdominal segments banded with yellow, the band on the third segment interrupted, while the third to ninth ventral segments are said to be margined with yellow laterally. In no specimen of *tabidus* examined by the writer is there any indication of a dorsal band of yellow on the abdomen nor are the ventral segments margined with yellow. Like *macilentus*, this species is therefore excluded from the synonymy. The description of *vittatus*, on the other hand, agrees closely with *tabidus*, and there seems to be no good reason why it should not be considered a pure synonym instead of a color variety.

Following is the complete synonymy of *Trachelus tabidus* as understood by the writer:

Trachelus tabidus (Fabricius) Jurine.

Sirex tabidus Fabricius (1), (2), (4).—Villers (5).—Linné (6).—Christ (8).—Fabricius (9).—Coquebert (10).—Walckenaer (11).—Rossi (19).—Herrich-Schäffer (26).—Duméril (29).

Tenthredo longicollis Fourcroy (3).—Villers (5).

Astutus tabidus Klug (12).—Panzer (15).

Cephus tabidus Fabricius (13).—Latreille (14).—Panzer (16).—Latreille (18).—Lepeletier (20).—Stephens (23).—Hartig (24).—Blanchard (25).—Lucas (27).—Costa (28).—Taschenberg (31).—André (33).—Cameron (34), (35).—Magretti (36).—Costa (37).—Dalla Torre (38).

Trachelus tabidus Jurine (17).—Curtis (22).—Konow (41), (42).—Rudow (43).—Kokujev (44).—MacGillivray (45).—Kholodkovsky (46).—Kulagin (47).—Kurdjumov (48).—Shtchegolev (49).—Uvarov (50).—Borodin (52).—Zolotarevsky (53).—Uvarov and Glazunov (54).—MacGillivray (55).—Howard (56).

Cephus nigritus Lepeletier (20).

Cephus vittatus Costa (32).

Calamenta johnsoni Ashmead (39).

Calamcuta johnsoni Ashmead (40).

Cephus pygmaeus Cory (51), not Linnaeus.

ADULT.

Female.—Long and slender, with abdomen somewhat compressed. Antennæ longer than thorax, thickened at apex, third joint slightly shorter than fourth, third to eighth joints four to five times as long as thick, those beyond eighth gradually shortening, the ones in thickened portion of antennæ subequal and not longer than broad; clypeus truncate at apex, with sharp lateral angles; occiput concave; greatest width of posterior orbit about equal to greatest transverse diameter of eye; pronotum elongate, nearly as long as broad, broadest at posterior margin, its sides more or less concave; mesoscutum and scutellum subequal in length; middle and hind tibiæ each with two apical spurs and normally each with two (sometimes one only) superapical spurs located at about the apical one-third of tibiæ; abdomen much longer than head and thorax, subcompressed, with sheaths broad and slightly thickened at apex. Polished black; mandibles except at apex, small spot below tegulæ, apex of front femora within, inner side of front tibiæ for its whole length, spot at apex of median femora in front, a broad longitudinal stripe along lateral margins of dorsal segments, a lateral spot on seventh ventral segment, and a narrow marginal stripe on basal part of sheaths yellow; wings subhyaline, nervures and stigma black. (See Pl. II, A.)

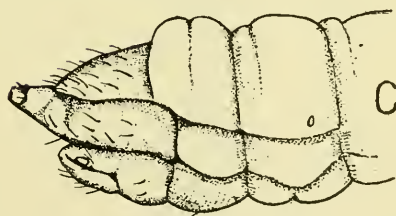
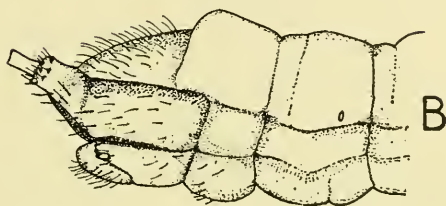
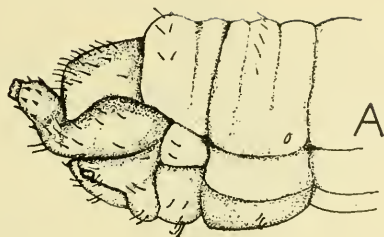
Male.—Similar to female in general appearance and color. Last visible ventral segment of abdomen prominent and extending beyond last dorsal segment; two ventral segments before last visible segment each with a broad, deep, horseshoe-shaped depression, within which is a transverse row of stiff, erect bristles. (See Pl. II, B.)

The only species occurring in America, so far as known, with which this species is likely to be confused are *Cephus cinctus* Norton and *Cephus pygmaeus* Linnaeus. The female may be readily distinguished by the fact that in both *cinctus* and *pygmaeus* the sheaths are narrower at apex than in the middle, and the dorsal segments are banded apically with yellow. The legs are also more largely yellowish. The male of *tabidus* differs from the males of the other two species in the presence of the horseshoe-shaped depression on the two ventral segments as well as by the color characters pointed out for the female.

OVERWINTERING LARVA.

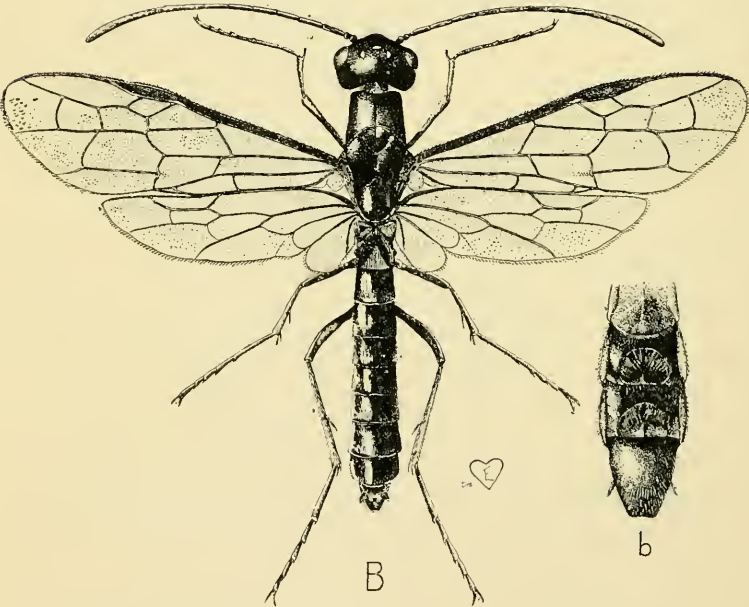
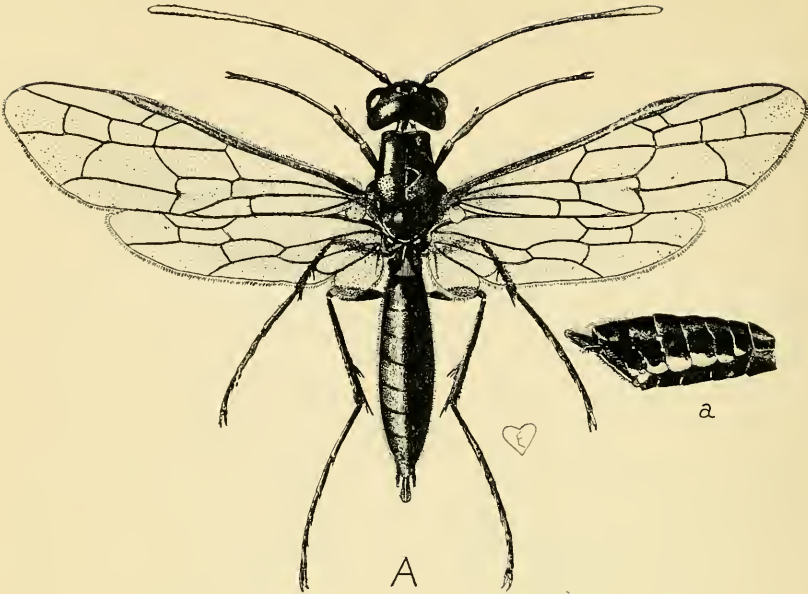
Body subcylindrical, yellowish white in color, 7 to 9 mm. in length, thoracic region slightly thicker than abdominal region. Living larvæ more or less tinged with greenish due to body contents.

Head pale yellow, its dorso-ventral length 1.1 mm., breadth 1.1 mm. Antennæ 5-jointed, tapering to a point at apex, more or less fuscous in color. Mandibles four-toothed, brownish, their apices nearly black; labrum, sutures about



THE BLACK GRAIN-STEM SAWFLY OF EUROPE IN THE UNITED STATES.

A, *Trachelus tabidus*: Lateral view of apical segments of larva; B, *Cephus cinctus*: Lateral view of apical segments of larva; C, *Cephus pygmaeus*: Lateral view of apical segments of larva.



TRACHELUS TABIDUS.

A, Adult female: a, Lateral view of female abdomen. B, Adult male: b, Ventral view of male abdomen.

clypeus, and articulations of mandibles brownish. Thoracic legs small, papilliform, and pale brownish. Dorsal abdominal segments triannulate; pleura prominent; ventral segments triannulate; prolegs absent. (For further description see Plate I, A, and key to larvæ.)

Larvæ of this species are apt to be confused with those of *Cephus pygmaeus* and *C. cinctus*. All three species infest the small grain crops in practically the same manner, have very similar biologies, and superficially resemble one another closely. The following key in conjunction with the accompanying figures will, it is believed, make it possible to recognize them:

KEY FOR SEPARATING GRAIN-INFESTING SAWFLY LARVÆ.

1. Dorsal anal lobe of the tenth tergite viewed from the side triangular, sloping gradually from base to apex, the anterior end of lobe much thicker than the posterior end which is more or less acute. Spines on the anal prong each arising from a small, more or less chitinized tubercle and closely grouped about the apex of the enlarged fleshy portion just basad of the short chitinized apical ring. Eighth and ninth tergites apparently glabrous.----- 2.
- Dorsal anal lobe viewed from the side not triangular, not sloping gradually from base to apex but convexly rounded, the posterior end of the lobe as thick dorso-ventrally as the anterior end and nearly perpendicular. Anal prong completely encircled by two irregular series of widely separated, short, stiff spines which do not arise from chitinized tubercles. Eighth and ninth tergites each with a transverse row of distinct short hairs. (See Plate I, A.)----- *Trachelus tabidus* Fab.
2. Anal prong terminating in a short chitinized ring which is not as long as broad. Spines basad of chitinized ring few in number, confined to a single transverse row on the dorsal surface. Dorsal, lateral, and ventral lobes all sparsely hairy. (See Pl. I, A.)----- *Cephus pygmaeus* Linn.
- Anal prong terminating in a chitinized tube-like process which is distinctly longer than broad. Spines basad of the apical tube-like process numerous, arranged in two irregular contiguous series completely encircling base of tube. Anal lobes all more distinctly hairy. (See Pl. I, A.)-----
- *Cephus cinctus* Nort.

MANNER OF WORK AND PROBABLE LIFE HISTORY.

Observations by the writer supplemented by those of McConnell and Myers, and confirmed in part by Kulagin (47) indicate that the life history of *Trachelus tabidus* does not differ greatly from that of the western grass-stem sawfly, *Cephus cinctus*. The early stages have not yet been observed in this country. Collections of adults in the field indicate that egg-laying takes place during the period May 15 to June 10. Some of the emergence records for reared specimens show somewhat earlier dates than May 15, but since these were obtained under the abnormal conditions of the laboratory they may be disregarded. Kulagin indicates about the same period for egg-laying in Russia:

The eggs are inserted in a slit made by the female in the stem some distance above the ground. The young larvæ burrow downward through the pith of the stem, hollowing it out to the base. The larvæ apparently attain full growth at about the time the grain is ripe. At the time the writer's investigations were begun, July 22, they were full grown and had evidently gone into hibernation. The fully-developed larvæ were, at this time, located at the extreme base of the stem, encased in a silken tube or lining to the burrow, this tube being two or three times the length of the larva and filling the hollow straw completely from about the surface of the ground downward. Above this silken tube the burrow is completely closed by a wad of frass. Before this wad of frass is put in place the larva almost completely severs the stem from the inside, this cut in nearly every case being at or very near the surface of the ground and usually a little above the first node on the stem where the surface roots put out. In making this cut just enough of the epidermis of the straw is left unsevered to attach it lightly and allow it to stand erect. In consequence of this cut the first slight bending of the ripened straw, as by a strong wind, causes it to snap off and fall.

Straws cut off by the insect are easily distinguishable from those severed by the harvester. The cut is exactly transverse to the stem and the ends of both the stub which remains in the ground and the fallen straw are distinctly concave or funnel-shaped. This appearance is so characteristic that one can readily detect the presence of the pest in a field by simply examining the ends of the fallen straws.

The hibernating larva, as already stated, is to be found in the stub of the wheat stalk remaining in the ground. Since this stub in most cases barely extends to the surface of the soil (sometimes a little above the surface), it is not always an easy matter to locate it. The fallen straws sometimes remain slightly attached on one side to the stub, and in such instances one can locate the infested stub by following the straw to its base. When the straw is completely detached, as is usually the case in a field that has been harvested, it is often necessary to search for some time before the stub containing the larva can be located.

The greater part of the insect's life cycle is apparently spent as a hibernating larva, this period extending from about the time the wheat is ripe enough to cut until some time the following spring when the larva changes to the pupa. Just when this change takes place has not been ascertained, but the pupal state is probably of short duration, as in *Cephus cinctus*; if so, the change to the pupa probably occurs in the latter part of April or early part of May. Adults, as already stated, are to be found in the fields during the latter half of May and early June.

In the case of one male specimen reared from wheat stubble by McConnell, the insect was collected as a larva September 30, 1915, and emerged as an adult May 3, 1917. This shows that under some conditions the life cycle may be extended over a two-year period. Such instances are probably rare under natural conditions, but the record indicates a high degree of adaptability on the part of the species for overcoming unfavorable conditions.

EXTENT AND CHARACTER OF INJURY.

Shortly after receipt of the complaint from Gaithersburg, and before the identity of the insect was known, the writer was detailed to visit the locality and investigate the nature and extent of the damage. Accordingly, on July 22, 1918, the farm of the correspondent, Mr. Beverly R. Codwise, was visited. It lies about 3 miles north of Gaithersburg on the road to Laytonsville, Md. Unfortunately the infested fields had already been harvested, making it practically impossible to estimate the extent of the actual injury. It was evident, however, that there had been an appreciable loss due to falling of the grain, so that it could not be picked up by the binder. The writer was informed that comment by passers-by on the large amount of grain missed by the binder had first called attention to the injury and caused the investigation which resulted in the sending of samples to the Bureau of Entomology.

Three other farms in the neighborhood of Gaithersburg were visited, on each of which the pest was located. Subsequently wheat fields in various other localities in Maryland and one in Virginia were visited, with the result that in every wheat field examined the insect was found to be present in varying abundance.

No actual counts of infested straw were made by the writer in any of the fields to ascertain the percentage of infestation. It was roughly estimated that in some of the worst cases the infestation amounted to 4 or 5 per cent. In most of the fields the infestation was much less than 4 per cent. Messrs. McConnell and Myers did make counts of the infested stubble on a small number of experimental plats and other fields of wheat at Carlisle and Mount Holly Springs, Pa., with the results showing an infestation varying from 4.36 per cent on one of the plats to 0.26 per cent on another, the average from all counts being 1.75 per cent.

That a 4 per cent infestation of stubble necessarily indicates a 4 per cent loss in the crop is not probable. The insect apparently chooses only well-developed and vigorous stems in which to oviposit, and some of these infested stems are known to develop at least partially filled heads. Just what the loss, if any, from failure of the heads on infested stalks to fill properly may be, remains to be determined.

It is certain that serious loss may and does occur because of falling of the grain due to the cut made by the larva preparatory to hibernation. The extent of this loss will in all probability depend in some degree upon weather conditions during the period of ripening of the grain. A heavy wind or severe storm at this time would cause most of the infested grain stalks to break off and fall so that they would not be picked up by the harvester. In the absence of such a wind or storm, the loss would undoubtedly be much less, but even with favorable conditions a certain percentage of the infested stalks would be broken off by the harvester reel and fall in front of the platform.

Kulagin (47) states that losses in Russia due to this species and *Cephus pygmaeus* are estimated at 14 to 20 per cent, although more severe in some cases. Shtchegolev (49) also reports 15 to 20 per cent injury due to these two pests. Other Russian writers record severe injury without specifying the amount. Unfortunately, in practically every instance these writers treat of the injury by *Cephus pygmaeus* and *Trachelus tabidus* collectively, without indicating how much of the damage is chargeable to each. This is no doubt due to the fact that they have been unable to distinguish the larvæ of the two species. Their records, therefore, do not afford a reliable basis for estimating the probable future importance of *Trachelus tabidus* in this country.

PARASITES.

In Russia two parasites of *Trachelus tabidus* have been recorded. *Collyria calcitrator* (Gravenhorst), an ichneumonid wasp, is apparently a common parasite of this species as well as of *Cephus pygmaeus*. Borodin (52) records the chalcidid *Arthrolysis* (*Picrocystus*) *scabricula* Nees as having been reared from these two saw-fly pests. Neither of these species has, as yet, been found in America.

The existence of at least one efficient parasite in America has, however, been established. Numerous specimens of a chalcidoid belonging to the genus *Pleurotropis* and apparently representing an undescribed species have been reared by Mr. W. R. McConnell at Mount Holly Springs and Carlisle, Pa. So far little is known of the life history of the species. It emerges from the prepupal larva of the *Trachelus* at about the time of emergence of the host adults and is believed to be a primary parasite, solitary in its habit. Observations to date are too limited in extent to form a very accurate estimate of the efficiency of this parasite, but in some instances at least it appears to exercise a considerable degree of control.

SUGGESTIONS FOR CONTROL.

In the present state of our knowledge of this species only suggestions of possible means of control can be given.

Measures for control will doubtless be similar to those against *Cephus cinctus*, the western grass-stem sawfly, and *Cephus pygmaeus*.

It is obviously impracticable to attack the insect in the egg stage or active larva stage, since both stages occur in the growing grain. The adult can not be reached by any known method. It appears, therefore, that control measures to be successful must either aim at destruction of the hibernating larva or pupa while in the stubble, where the insect passes the greater part of its existence, or be confined to cultural methods such as crop rotation. The fact that the larva is located in the part of the stem below the surface of the ground precludes the possibility of accomplishing anything by any ordinary burning of the stubble. Disking the stubble thoroughly as soon after cutting the grain as practicable would possibly be of benefit by turning the infested stubble out and thus exposing the larva to the action of summer heat and winter cold. The larva is quite hardy, however, and only experimentation will prove or disprove the effectiveness of disking.

In Russia plowing down of the stubble as deeply as possible is recommended against this species as well as against *Cephus pygmaeus*. The same treatment is recommended and has proved successful against *Cephus cinctus* in this country, and it seems the logical treatment for adoption against this species. To be effective the plowing must bury the stub containing the larva so deeply that the maturing adult will be unable to escape. Shallow plowing will not suffice, as the adults undoubtedly will be able to burrow their way out if covered with only 2 or 3 inches of soil. Deep and clean plowing, therefore, will be essential. The plowing may be done at any time between the cutting of the grain and the following spring prior to emergence of the adults in April or May.

If, as now seems probable, this insect confines itself, in this country, to the small-grain crops as host plants, there can be little doubt that crop rotation will prove an effective means of reducing damage from it. Wheat, barley, or rye should be followed by some crop which will not serve as a host plant, such as corn or truck crops. The present practice on some farms of growing wheat on the same ground two years in succession is distinctly favorable to the propagation of the pest since the adults upon emerging find themselves surrounded by ideal conditions for oviposition. The practice also of sowing grass or clover with wheat and allowing the wheat stubble containing the larva to stand undisturbed for two seasons could hardly be improved upon as means of increasing the numbers of this insect. Any system of rotation to be effective should insure thorough plowing down of the wheat stubble and the growing of some crop other than a small grain following wheat.

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L. O. HOWARD, Chief



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June 3, 1920

CONTROL OF THE GRAPE-BERRY MOTH IN NORTHERN OHIO.

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INTRODUCTION.

The grape-berry moth (*Polychrosis viteana* Clem.) has been the most destructive insect pest with which the grape growers of northern Ohio have ever had to contend. In an effort to improve the methods of control for this insect, extensive experiments in cooperation with the Ohio Agricultural Experiment Station were conducted during the seasons of 1916, 1917, and 1918 in northern Ohio. The results of these experiments and the recommendations based thereon are contained in this paper, together with observations made during the investigation. Only such life-history data are presented as are necessary for the understanding of the control experiments. The complete life-history data will be presented in a later paper.

¹ This investigation was conducted under the direction of Dr. A. L. Quaintance, Entomologist in Charge of Deciduous Fruit Insect Investigations of the Bureau of Entomology. The senior author, assisted by E. R. Selkregg, then field assistant in the Bureau of Entomology, conducted the work during the season of 1916. Much credit is due Dwight Isely of the Bureau of Entomology for his suggestions on grape-insect control, based on similar investigations in the Chautauqua-Erie grape belt of Pennsylvania. The results of Mr. Isely's investigations are published in United States Department of Agriculture Bulletin No. 550. The authors wish to express their appreciation to Prof. H. A. Gossard, entomologist of the Ohio Agricultural Experiment Station, for his help in many ways. To the many grape growers who have cooperated most willingly the authors express their thanks.

HISTORY IN OHIO.

The grape-berry moth was destructive in Ohio as early as 1869, according to Goodwin.¹ This was shortly after grape production became an extensive industry in the State. In 1881 the insect is recorded as having been especially destructive on the islands in Lake Erie.¹ Injury in Ohio was extensive again in 1905 and 1906, but later decreased and in 1909 and 1910 the berry moth caused comparatively little damage.^{1, 2} The infestation became severe again in 1913 and 1914 and reached its height in 1915, when in some local sections as much as two-thirds of the entire crop was ruined. The infestation continued high in 1916, the first season of the investigations here reported, and was but slightly less in 1917. Due to a cold autumn, however, the commercial damage was much less in 1917 than in any one of the four years preceding. In 1918, the last year of these investigations, the infestation about Cleveland was of no commercial importance, but in the section about Sandusky the loss was heavy in many unsprayed Catawba vineyards.

NORTHERN OHIO CONDITIONS AFFECTING INFESTATION.

The grape-berry moth has been a more general pest in the northern Ohio section than in the commercial grape sections of New York, Pennsylvania, or Michigan. This statement is based on published reports^{3, 4} and on observations made by the senior author during the seasons of 1914-1918 inclusive.

Four principal factors have brought about this condition: The varieties grown, the cultural practices, the method of harvest, and the training system.

VARIETIES GROWN.

The Catawba variety predominates in the grape section about Sandusky and on the neighboring Lake Erie islands. Due to its late harvest this variety offers ideal conditions for the second-brood larvæ to mature and to reach winter quarters. In all the experimental work conducted the Catawba variety has been uniformly infested more heavily than the Concord, which is the predominating variety in the Chautauqua-Erie belt of Pennsylvania and New York and in Michigan sections.

CULTURAL PRACTICES.

Late in the fall, after grape harvest, a majority of the vineyards are "plowed on." This operation consists in beginning next to the

¹ Goodwin, W. H. The grape-berry worm (*Polychrosis vitcana* Clemens). Ohio Agr. Exp. Sta. Bul. 293, p. 259-307 (20 pl. on p. 288-307). 1916.

² Gossard, H. A., and Houser, J. S. The grape-berry worm. Ohio Agr. Exp. Sta. Circ. 63. 16 p., fig. 1906.

³ Johnson, Fred, and Hammar, A. G. The grape-berry moth. U. S. Dept. Agr. Bur. Ent. Bul. 116, Pt. II, p. 15-71, fig. 4-22, pl. 4-8. 1912.

⁴ Isely, Dwight. Control of the grape-berry moth in the Erie-Chautauqua grape belt. U. S. Dept. Agr. Bul. 550. 44 p., 9 fig., 6 pl. 1917.

vines and plowing three successive furrows of soil toward the vines. Thus all leaves and trash in the vineyard are covered with from 3 to 5 inches of soil and ideal winter protection is afforded the hibernating pupæ which are in cocoons in the old grape leaves (Pl. II, fig. 2). In the spring before time for moth emergence this soil is worked away from the vines. In the Sandusky region it is plowed away and in grape sections near Cleveland it is removed with a disk or worked away with a shovel cultivator. This cultivation breaks the crust formed in the winter and in many cases turns to the surface the pupæ (Pl. I, fig. 3) that were plowed under the previous fall. This practice of covering the pupæ for the winter and then uncovering them early in the spring protects them from the extreme winter and allows the moths to emerge in the spring.

Pupæ of the berry moth, kept in the insectary yard at Sandusky under conditions similar to those described for the vineyards, lived through the winters of 1916-17 and 1917-18. In the spring of 1917 the emergence was 20 per cent and in 1918, after an unusually severe winter, it was 26 per cent. Comparative data are not at hand for the same winters with pupæ exposed as they would be in a vineyard plowed before grape harvest and then left until spring. In experimental work reported by Isely,¹ however, it was found that subsequent emergence from cocoons left through the winter of 1915-16 under exposed conditions in the vineyard was but 5 per cent as compared with 30 per cent emergence where the cocoons were covered by 2 inches of earth and then uncovered before time for emergence in the spring.

Since late plowing away in the spring is objectionable in northern Ohio from a horticultural standpoint, the writers recommend that when cultivation is completed in July the vineyards, whenever possible, be placed in final cultural condition for the winter and then that they be left in that condition until the next spring. The only objection to this practice is the excessive growth of weeds, which interferes with harvesting. This can be overcome by seeding a cover crop at the completion of cultivation.

METHOD OF HARVEST.

A large part of all the grapes in these sections and practically all of the Catawba variety were formerly sold for wine making. Since no particular packing is required for this market, all sorting is done in the vineyards by the pickers. Wormy berries are cut or shaken out of the clusters and allowed to fall to the ground and to remain in the vineyard. It appears that any other method of disposing of the infested grapes would be more costly in labor than would be warranted now that satisfactory control may be secured by spraying.

¹ Isely, Dwight, *op. cit.*

TRAINING SYSTEM.

The "fan" system of grape training (Pl. III, fig. 1) which is used consistently in northern Ohio with the Catawba variety and a modification of which is used with Concord, is not generally practiced in any of the other commercial grape sections of the country.

This "fan" system consists in securing the bearing canes from the old vine head between the ground and the first wire and tying them up obliquely to the first and second wires, forming a V open at the top. Although two canes are the rule with the Catawba variety, when the thrift of the vine allows of more than two the additional canes are also carried up obliquely, completing the fan from which the system takes its name. As the young shoots bearing the clusters grow to a sufficient length they are tied up vertically to the middle and top wires. An effort is made to have these shoots spread, but to economize labor in tying they are often bunched 2 to 4 in a place. This system of training spreads the grape clusters all through the vine from the ground to the top wire and covers them almost completely with foliage and shoots (Pl. III, fig. 2). These conditions explain in part the failure to cover the grape clusters when any set-nozzle method of spraying is used, particularly when the spraying is done late in the season and considerable vine growth has been attained.

VARIETAL INFESTATION.

Several commercial varieties of grapes are present in northern Ohio, affording opportunity for observation on the relative infestation of the different varieties by the grape-berry moth. A list of varieties observed, beginning with the most heavily infested and ending with the least, is as follows: Shride, Elvira, Clinton, Reisling, Catawba, Norton, Niagara, Delaware, Agawam, Ives, Concord, Worden, and Moores Early.

In general it seems that the early-blooming varieties like the Shride and Clinton become heavily infested with the first-brood larvæ, and late-harvested varieties like Catawbas and Nortons become heavily infested with second-brood larvæ.

SEASONAL HISTORY.

The grape-berry moth completes one life cycle and a part of another each season. This insect is injurious only in the larval stage. There are two broods of worms or larvæ every season (Pl. I, fig. 1), the second much more numerous and destructive than the first (Pl. II, fig. 1). Since an understanding of the main points in the life history of the insect is necessary for the best application of control methods, a brief summary will be given.

The winter is spent in the pupal stage in cocoons (Pl. I, fig. 2) which the larvæ spin in grape leaves the previous fall. These leaves are the ones that fall early and become soft and sodden on the ground (Pl. II, fig. 2) and remain under the trellis during the winter. In the spring, previous to and during grape bloom, moths (Pl. I, figs. 4, 5) begin to emerge from the overwintering pupæ. This emergence gradually increases and continues at a high point for about 3 weeks. The moths begin to deposit eggs on the young grapes about 4 days after emergence and the eggs hatch in from 4 to 6 days. This first brood of larvæ or worms usually is not seriously destructive, though first-brood infestation amounting to as much as 30 to 35 per cent has been observed. The average length of the feeding period of this brood of larvæ is 23 days. When mature the larvæ migrate to grape leaves on the vines and spin their cocoons on them. From the cocoons moths emerge in about 13 days and begin laying eggs about 4 days later. The eggs of this second brood are placed on the nearly full-grown grapes and are easily found where the infestation is heavy. Before the eggs hatch they appear as creamy-white raised dots on the green grape berries, but after the larvæ leave the eggs the eggshells appear as glistening white spots. This brood of eggs hatches in from 4 to 6 days and it is the resultant brood of larvæ that, if allowed to develop, does the greatest damage to the grape crop. (Pl. II, fig. 1.) The larvæ of this brood feed for a long period and usually leave the grapes just before harvest. They spin down to the ground and make their winter cocoons on old decayed grape leaves under the trellis. In the case of a cold fall many larvæ do not leave the grapes but are harvested with the grape crop. This condition prevailed in the fall of 1917 to an unusual degree and the result was a lighter infestation in 1918.

RELATION BETWEEN SEASONAL-HISTORY DATA AND CONTROL MEASURES.

The control experiments recorded in this bulletin are based on extensive field observations and on life-history studies conducted each season. The data shown in diagram form in figure 1 are summarized from the complete seasonal-history data. In determining the hatching periods of the larvæ 4 days are allowed from the emergence of the moths to the deposition of eggs and 6 days for incubation of the eggs. These are average figures from many observations extending over several seasons.

It is seen in figure 1 that in 1916 and 1917 a few larvæ had hatched before Concord grapes began to bloom and in 1918 that the dates of first hatching and beginning of bloom are coincident. In each season the first-brood larvæ were hatching in large numbers for about

3 weeks. It is important to note that the rise in the early part of the hatching is abrupt and the subsidence of hatching more gradual.

It has been the opinion of other writers that the largest part of the second-brood larvæ hatch within a shorter period of time than the first brood. The rearing records here illustrated do not support that belief but show the hatching periods to be of about equal length.

NATURAL CONTROL OF FIRST-BROOD LARVÆ.

It was observed that the grape berries infested by first-brood larvæ dropped readily from the vines when touched. It was thought that if these infested berries dropped in any great numbers at any particular time some cultural method such as covering these berries with soil might aid in the control of the insect. To determine this

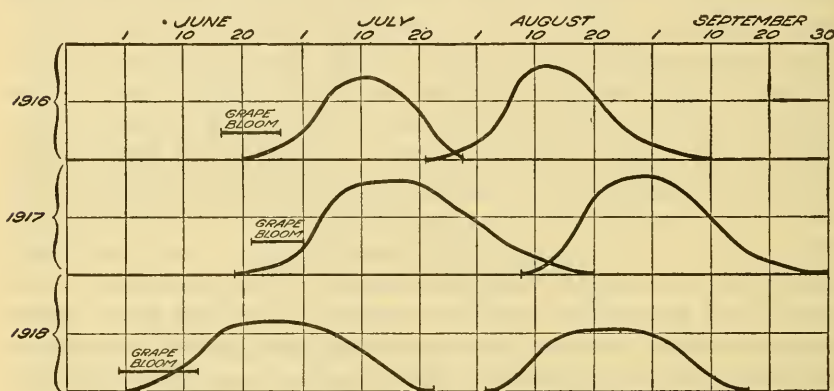


FIG. 1.—Diagram showing relation between dates of spray application and periods during which the grape-berry moth larvæ were hatching for the seasons 1916, 1917, and 1918 at Sandusky, Ohio.

point the following experiment was undertaken in 1916: Wooden frames were made, 6 feet long, 30 inches wide, and 6 inches deep with cheesecloth stretched on the bottoms. These trays fitted between the vines directly under the trellis and were placed in six different locations in the vineyard, under vines heavily infested with first-brood larvæ. Fresh leaves were supplied in the trays for the cocooning of any larvæ that might drop. The trays were put in place July 5 when first-brood infestation was about at its height and were left until August 15, when practically all first-brood larvæ had left the grapes. These trays were examined every three days. Practically no grapes dropped from the vines and not a single larva was taken throughout that period. From these negative results it is concluded that practically no natural control occurs from the dropping of grapes infested by first-brood larvæ.

CONTROL EXPERIMENTS.

STATUS OF SPRAY PRACTICE FOR GRAPE-BERRY MOTH CONTROL.

When these investigations were undertaken the following principal facts were known about spraying for the control of the grape-berry moth: First, satisfactory control had not been effected by the use of any system of set-nozzle spraying, particularly in thrifty vineyards where foliage growth was heavy. Second, satisfactory control had been effected in Ohio¹ by using the trailer method of spraying at the time of the hatchings of second-brood larvæ, usually in early August. This practice, however, left a heavy residue of spray material on the fruit at harvest time, which tended to exclude such fruit from a basket market. Third, two spray applications by the trailer method, the last when the grapes first touched in the clusters, had given satisfactory control on the Concord variety in the Chautauqua-Erie belt in 1915. This practice was to be thoroughly tried in northern Ohio on Concord and Catawbas.

SCOPE OF EXPERIMENTS.

From this summary of the knowledge available it appeared that the investigations should deal with three main points: (1) Time and number of spray applications, (2) chemicals used in spray materials, (3) spray residues left at harvest time.

In studying these factors spraying experiments were conducted by the writers in 6 vineyards in 1916, in 9 in 1917, and in 15 in 1918, a total of 30 vineyards. These vineyards were selected for the opportunity they offered for the advantageous study of any one or more of the important features enumerated above. Since little would be gained by considering each vineyard separately it has seemed desirable to assemble in Tables I, II, and III the data relating to the different vineyards and to bring together in similar form in Table IV the results of the experiments.

TIME OF SPRAY APPLICATIONS.

Former experiments² indicated that a spray application directly after grape blooming was important for the control of both grape rootworm beetles and grape-berry moth larvæ. In the Sandusky and island sections of Ohio a spray application following grape bloom is usually made for the control of downy mildew, *Plasmophora viticola*, particularly on Catawba and Delaware varieties. This application directly following grape bloom was considered as the first spray in all of the experiments in which it was included. The second spray

¹ Goodwin, W. H., op. cit.

² Goodwin, W. H., op. cit. Johnson, Fred, and Hammer, A. G., op. cit. Isely, Dwight, op. cit.

was applied when the grapes touched in the clusters, but before the clusters were tight enough to prevent the spray material from being driven between the grapes. This stage of grape growth usually occurs from 3 to 4 weeks after bloom. This second spraying was designed to kill the late hatching first-brood larvæ and to remain on the grapes to be effective when the second-brood larvæ hatched. The third spraying was timed in each case to precede immediately the hatching period of the majority of second-brood larvæ.

METHOD OF APPLICATION.

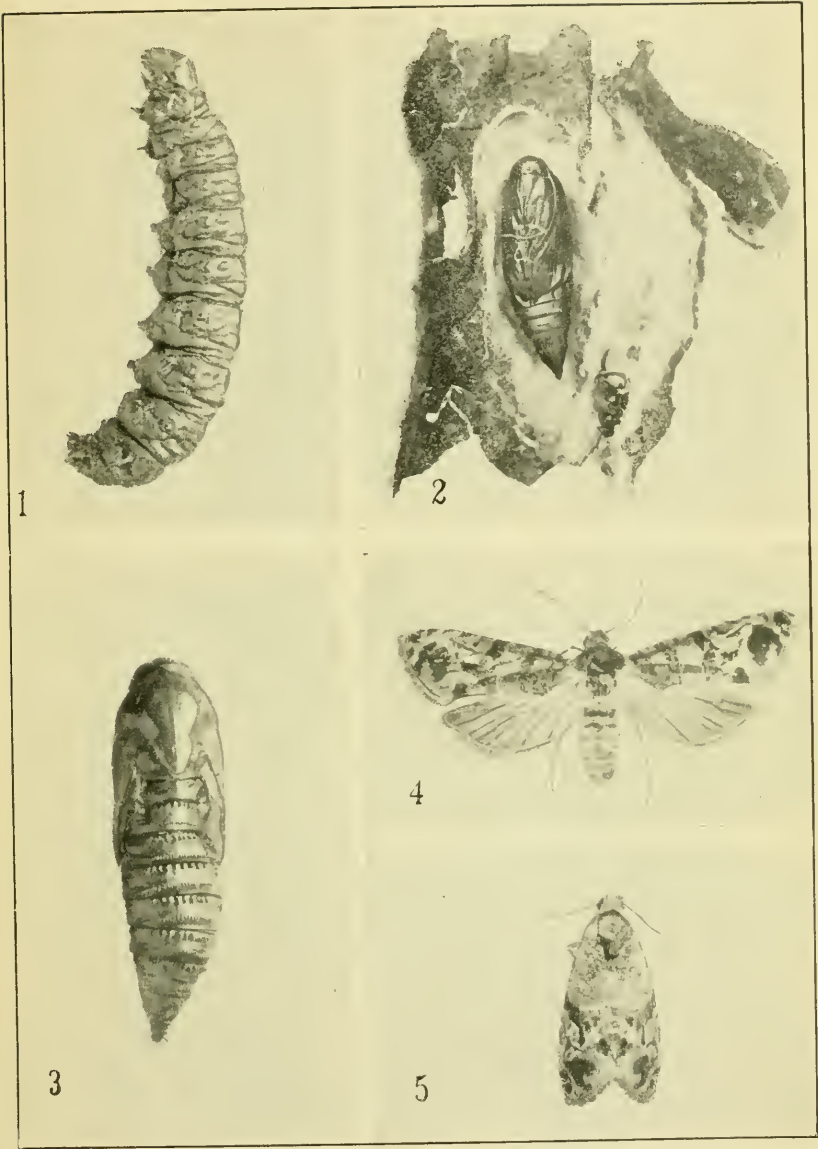
All spraying was done by the hand or trailer method in which 2 hose lines of from 20 to 50 feet trail behind the sprayer, and the spray material is delivered through short spray rods and angle nozzles, directed by hand as in tree spraying. Variations in this method will be discussed later. Sufficient pressure was maintained to drive the spray well into the clusters, but the amount of pressure varied from 125 to 225 pounds in different vineyards. The best pressure to maintain will vary somewhat with the vineyards, but the writers believe that from 175 to 225 pounds usually will be found most efficient. Nozzles set at an angle are absolutely necessary for efficient work, and it was found that nozzles set at angles of 45° allowed more freedom of handling than those set at 90°. A nozzle aperture of $\frac{1}{16}$ -inch was most commonly used, but the most efficient size was found to vary with the vineyard and other local conditions.

WEATHER CONDITIONS¹ AFFECTING SPRAY RESULTS.

The season of 1916 was about normal in all respects except for an unusually dry period during July and August which was favorable for spraying and for spray material adhering. These same conditions were likewise favorable for the development of an unusually large second brood of worms. September and October were warm and dry, conditions also favorable to extensive berry moth injury as shown in the uniformly heavy infestation in the checks (Table IV).

In 1917 conditions were decidedly unfavorable for spraying operations. Both the first and second applications were interfered with by rain and closely followed by showers of varying intensities. In July the total rainfall was but 0.46 inch, but this came between the first and second spray applications. The maturing of first-brood larvæ was favored by an exceedingly hot and dry period from July 28 to August 6 and a subsequent heavy hatching of second-brood larvæ followed. September was 3.3° below normal in temperature and slightly below in precipitation, while October was 8.3° below normal with 3.79 inches of rainfall above normal. These unfavorable

¹ Weather records from the U. S. Weather Bureau Station at Sandusky, Ohio.

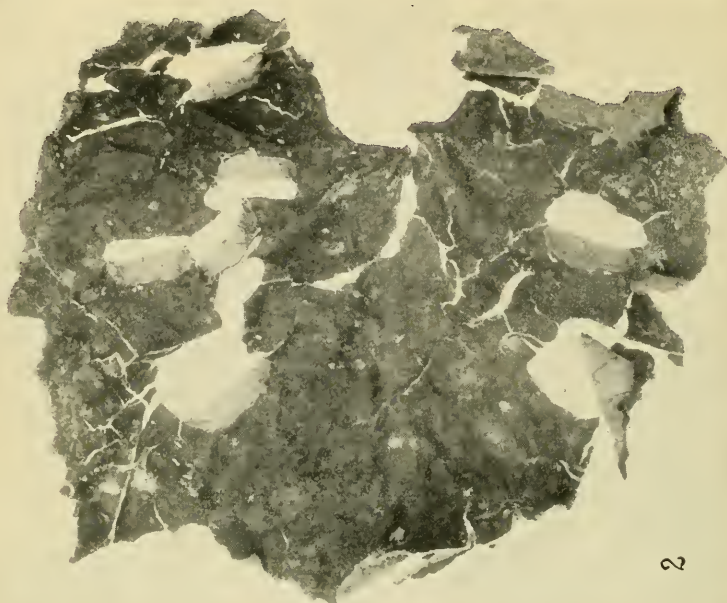


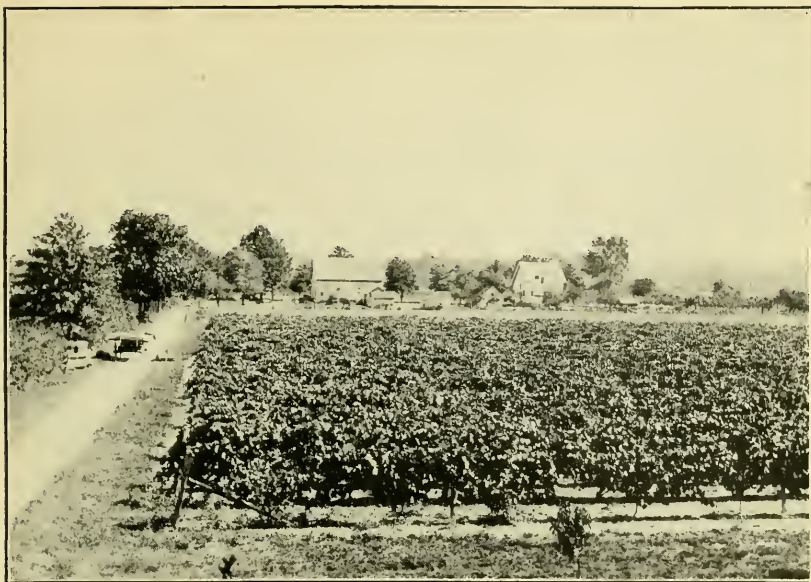
THE GRAPE-BERRY MOTH (*POLYCHROSIS VITEANA*).

FIG. 1.—Larva. FIG. 2.—Pupa (ventral aspect) in cocoon. FIG. 3.—Pupa (dorsal aspect). FIGS. 4, 5.—Adult. All greatly enlarged.

DAMAGE BY THE GRAPE-BERRY MOTH.

FIG. 1.—Grape cluster at harvest time, heavily infested with second-brood grape-berry moth larvae. FIG. 2.—Cocoons in sodden grape leaf under trellis.





THE "FAN" SYSTEM OF GRAPE TRAINING.

FIG. 1.—Northern Ohio vineyard trained according to the fan system. FIG. 2.—Grapevine showing fan system of training with grape clusters scattered from near the ground to the top wire.

conditions in September and October retarded the development of second-brood larvæ and counteracted the previous favorable conditions.

The season of 1918 opened unusually early and continued favorable for all growth processes throughout the season. Spraying was but little interfered with and no unusual weather conditions prevailed that affected the spraying results.

SPRAYING EXPERIMENTS IN 1916.

TABLE I.—*Vineyards used for spraying experiments in northern Ohio, 1916.*

Vineyard No.	Vineyard owner and location.	Varieties.	Dates of spray applications.			Estimated infestation 1915.	Gallons of spray material per acre.		
			First.	Second.	Third.		First.	Second.	Third.
1	Roland Brown, Kelleys Island.	Catawbas.	July 5	July 21	Aug. 9	<i>Per ct.</i> 70	173	192	192
2	O. W. Brown, Kelleys Island.	do.....	July 3	July 20	do...	85	120	202	200
3	Charles Duggan, Put-in-Bay.	do.....	June 30	July 17	Aug. 7	75	112	176	112
4	W. R. Huntington, Put-in-Bay.	Catawbas, Concords.	July 1	July 19	Aug. 8	80	105	160	112
5	E. Manty, Venice.....	do.....	June 29	July 12	Aug. 3	90	128	304	150
6	John Schonhart, Venice.	do.....	June 27, 28.	July 11, 12.	Aug. 2	70	90	236	230

Experiments were conducted in six vineyards in the Sandusky and island sections, as shown in Table I. In all of these experiments the arsenicals were applied in Bordeaux either 3-3-50 or 2-3-50 strength. Laundry soap at the rate of 2 pounds to 50 gallons was used for the first spray application in all of the vineyards and for the second spray in vineyards Nos. 5 and 6. It became apparent during the second spray application that resin fish-oil soap possessed better spreading qualities than laundry soap and so it was used in all the other spray applications at the rate of 1 pound to 50 gallons. Previous to bloom all of the vineyards received an application of Bordeaux alone for the control of downy mildew. The strength of arsenicals in the berry-moth sprays was varied in the different vineyards as shown in Table VI.

SPRAYING EXPERIMENTS IN 1917.

TABLE II.—*Vineyards used for spraying experiments in northern Ohio, 1917.*

Vineyard No.	Vineyard owner and location.	Varieties.	Dates of spray applications.			Estimated infestation 1916.	Control of grape-berry moth in 1916.	Gallons of spray material per acre.		
			First.	Second.	Third.			Spray applications.		
								First.	Second.	Third.
						<i>Per ct.</i>				
1	Becker Wine Co., Kellys Island.	Catawbas	July 14	Aug. 3, 4	.....	25	(1)	150	193	.....
2	O. W. Brown, Kellys Island.	do.....	July 12	Aug. 2	.....	50	(2)	165	178	.....
3	Paul Cooley, Dover Center.	Concords	July 12, 13.	July 26	Aug. 18	40	(3)	250	300	300
4	Fred Foye, Put-in-Bay.	Catawbas	July 11, 12.	July 31, Aug. 1.	.....	90	(3)	150	233	.....
5	George Lewis, Bay Village.	Concords, Ives.	July 5-9	July 23-26.	Aug. 17	40	(3)	200	275	200
6	John Schonhart, Venice.	Catawbas, Concords.	July 3, 4	July 20-25.	Aug. 14	20	(4)	150	312	280
7	T. W. Wearsch, Avon Lake.	Concords, Ives.	July 10	July 27	Aug. 17	90	(3)	120	160	160

¹ One spray with trailers.² Two sprays with trailers but operators riding.³ No spray.⁴ Two sprays with trailers.

As seen in Table II the experiments were conducted in seven vineyards, four in the Sandusky and island sections and three in the Dover and Avon sections just west of Cleveland, Ohio. The experiments were so placed as to include local variations in the different grape sections, such as weather, cultural practices, varieties, and markets. All the arsenicals were applied in Bordeaux 2-3-50 with resin fish-oil soap added at the rate of 1 pound to 50 gallons. The following single exception was made: In vineyard No. 5 copper sulphate was omitted from the third spray application and laundry soap, 2 pounds to 50 gallons, was substituted for resin fish-oil soap.

SPRAYING EXPERIMENTS IN 1918.

TABLE III.—*Vineyards used for spraying experiments in Northern Ohio, 1918.*

Vineyard No.	Vineyard owner and location.	Varieties.	Date sof spray applica- tions.			Estimated infestation 1917.	Control of grape- berry moth in 1917.	Gallons of spray material per acre.		
			First.	Second.	Third.			Spray applications.		
								First.	Sec- ond.	Third.
1	C. D. Powell, Ver- milion.	Ives.....	June 13, 14.	July 9	Aug. 5	Per ct. 15	(1)	(2)	(2)	(2)
2	O. W. Brown, Kel- leys Island.	Catawbas	June 29	July 18	.....	15	(1)	(2)	(2)	(2)
3	T. W. Wearsch, Avon Lake.	Concords, Ives.	June 14, 15.	July 11, 12.	.....	2	(1)	100	150	.....
4	Ernest Dunning, Avon Lake.	Concords..	June 19	July 16	.....	50	(2)	200	342	.....
5	V. Doller, Put-in- Bay.	Catawbas	July 2-3	Omitted.	.....	75	(2)	(2)	(2)	.....

¹ Two sprays with trailers.² No record.³ No spray.

The experiments were extended in 1918 to include work in 15 vineyards, but as infestation was not sufficiently heavy for satisfactory comparisons in all the vineyards only the 5 showing the heaviest infestations are included in Tables III and IV.

The arsenicals were applied in Bordeaux 2-2-50 in vineyards Nos. 1, 2, and 5. In vineyards Nos. 3 and 4 copper sulphate was omitted at the request of the owners. Stone lime 2 pounds to 50 gallons was retained to care for any free arsenic in the arsenicals. Resin fish-oil soap at the rate of 1 pound to 50 gallons was used uniformly throughout the experiments.

METHOD OF RECORDING RESULTS OF SPRAYING EXPERIMENTS.

It had been learned in earlier work ¹ that results based on weights of harvested fruit were misleading, owing to the varying thrift of vineyards, time of harvest, weather conditions affecting the development of worms, etc. The weight method, therefore, was abandoned in favor of the count method. This consists in selecting a representative number of vines in each sprayed plat and in each check, harvesting all the fruit from these vines, counting the clusters, then the clusters containing wormy berries, then removing the wormy grapes and counting them. To ascertain the average number of grapes per cluster, 100 representative clusters were taken in each vineyard and all the grapes counted. The number of clusters in each plat was then multiplied by the average number of grapes per cluster to give the total number of grapes examined in each plat.

In all control work on the grape-berry moth, the unevenness of infestation within a vineyard has made experimental results difficult to interpret. This uneven infestation prevailed throughout these investigations but was cared for whenever possible by placing checks across the control plats and reading the results on the control plat the second post-length away from the checks. While the plan does not entirely overcome the difficulty, the writers feel that the averages from several vineyards closely approximate actual conditions.

In all cases the fruit from at least 10 vines was examined and when possible the examinations included all the fruit from 20 to 25 vines. Exceptions to this occurred only when there were less than 10 vines of a particular variety in a plat. First-brood counts were made in some instances, but since they add little to the final results they are omitted from the tables.

¹ Johnson, Fred, and Hammar, A. G., op. cit.; Isely, Dwight, op. cit.

SUMMARY OF RESULTS BY VINEYARDS, TIME AND NUMBER OF SPRAY APPLICATIONS, 1916, 1917, 1918.

TABLE IV.—Summary by vineyards of spraying results for control of the grape-berry moth, *Sandusky, Ohio, seasons 1916, 1917, 1918.*

[All spray applications made by the hand or trailer method.]

SEASON 1916.

Number of applications.	Spray mixture.		Combination of spray applications.			Varieties used.	Vineyard No. 1.		Vineyard No. 2.		Vineyard No. 3.		Vineyard No. 4.		Vineyard No. 5.		Vineyard No. 6.		Vineyard No. 7.		Averages of all vineyards.	
	Arsenate of lead powder.	Material.	First.	Second.	Third.		Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.
2	2½	Galls.	X	X		Catawbas.	31.59	98.26	28.29	63.50	6.28	78.75			22.74	94.99	10.41	64.39			19.86	79.98
2	2½		X	X		Concords.							3.25	64.52	10.20	90.93	3.34	43.32			5.59	66.25
2	2½		X	X		Catawbas.	33.54	98.26			8.27	78.75					15.17	77.93			18.99	83.98
2	2½			X	X	Concords.					7.67	78.75		81.12			2.31	41.16			2.31	22.67
2	2½			X	X	Catawbas.							1.37				8.31	77.93			5.78	79.27
2	1½		X	X		Concords.							.93	81.12			2.66	22.67			2.66	22.67
2	2½		X	X		Catawbas.											11.90	70.26			6.41	75.69
3	2½		X	X	X	Concords.	16.96	98.26	9.06	63.50	3.62	78.75			2.48	94.99	5.56	52.83			5.56	52.83
3	1½		X, 1½ lbs.	X, 1½ lbs.	X, 2½ lbs.	Catawbas.							2.26	64.52	1.48	90.93	2.18	64.39			6.86	79.98
1	2½		X	X		Concords.							.81	81.12			.21	43.32			1.32	66.26
						Catawbas.					13.30	78.75									.81	81.12
						Concords.							2.37	81.12			22.78	74.24			12.82	78.04
																	11.48	33.68			11.48	33.68

SEASON 1917.

2	2½		X	X		Catawbas.	0.67	64.09	6.47	79.31			7.72	79.63			0.48	30.14			4.95	74.34
						Concords.																30.14
						Ives.											2.11	39.67			2.11	39.67

2	1½	50	X	X	...	{Catwabs. Concords.	2.03	64.09	8.86	78.17	...	5.54	53.03	...	1.48	42.00	...	2.66	88.03	...	4.55
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1.04
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	50.57
2	1½	50	X	X	X	{Concords	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1.68
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	19.86
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	35.64
3	1½	50	X	X	X	{Catwabs. Concords.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1.11
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	49.28
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	42.00
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.41
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1.21
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	52.96
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1.67
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	19.59
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6.52
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	60.57
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	32.68
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	70
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	20.87
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	81.49
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	30.14
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	.94
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	39.67
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	7.23
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	39.67
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	20.64
						{Ives.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	46.52

SEASON 1918.

[illegible]

In Table IV are brought together all of the data bearing on the time and number of spray applications, arranged by vineyards and varieties. This table provides for a comparison of the plats within each vineyard by reading from top to bottom, as well as a comparison of the plats receiving similar spray treatment in the different vineyards, by reading across. While the comparison between plats within a vineyard is relatively consistent, considerable variations exist between vineyards. A study of the column of averages shows satisfactory commercial control to have been effected in all plats which received either two or three spray applications with the exceptions of the first two plats. These two plats illustrate the necessity of timeliness of spraying and adhesiveness of spray material, since in 1917 the more timely spray treatment, and the use of resin fish-oil soap throughout, reduced the average infestation from 19 per cent in 1916 to 5 per cent in 1917.

RELATIVE EFFICIENCY OF DIFFERENT TIMES AND NUMBERS OF SPRAY APPLICATIONS.

TABLE V.—*Summarized results from Table IV—relative efficiency of different times and numbers of spray applications, 1916, 1917, and 1918—Arsenicals applied in Bordeaux mixture and soap solution.*

Number of applications.	First, 3 to 5 days after bloom.	Second, when grape berries touch in cluster.	Third, when second-brood larvae begin to hatch.	Arsenate of lead powder, pounds to 50 gallons material.	Years tried.	Number of vineyards.	Number of plats.	Percentage of grape berries infested, averages of all experiments, 1916, 1917, 1918.					
								Catawbas.		Concords.		Ives.	
								Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.
2.....	X	X	.....	2½	1916, 1917	9	11	11.35	79.22	3.04	48.20	2.11	39.67
2.....	X	X	X	2½	1916	3	4	18.99	83.98	2.31	22.67	.....	.....
2.....	X	X	.....	1½	1917, 1918	11	14	4.67	64.92	.82	26.00	1.53	16.85
2.....	X	X	X	1½	1917, 1918	5	6	.....	.....	1.11	35.64	2.07	30.14
2.....	.....	X	X	2½	1916	3	4	5.78	79.27	2.66	22.67	.....	.....
3.....	X	X	X	2½	1916	6	8	6.86	79.98	1.32	66.26	.....	.....
3.....	X	X	X	1½	1917, 1918	5	5	.41	42.00	1.21	52.96	1.31	17.92
1.....	.....	X	.....	2½	1916, 1917	6	7	16.90	79.77	6.21	31.91	7.23	39.67
1.....	X	.....	.....	1½	1917, 1918	4	4	.....	.....	13.30	26.40	8.75	9.89
2.....	X	X	.....	1	1918	2	2	7.39	62.36	.....	.....	2.08	6.93
1.....	.....	X	.....	1½	1918	2	2	25.67	82.82	.....	.....	4.20	10.04

A comparison of the combinations of the first and second sprays with first and third sprays shows little choice between them as far as berry-moth control is concerned. Since the combination of the first and second sprays leaves the fruit practically free of all spray residue at harvest time and since the second spray is more easily applied than the third because of lighter grape foliage, this combination of the first and second application is preferred by the writers. It is important to know, however, that if for any reason the second spray can not be made, the third may be applied and will give about

equally as good control. When the third application is made the fruit will usually be unfit for basket market because of excessive spray residue.

Where a third application is added to the first and second, control is slightly better, 6.8 per cent infestation as compared with 11.3 per cent in 1916 and 0.4 per cent as compared with 4.6 per cent, an average for 1917 and 1918. These differences, however, were not sufficient to justify the expense of the third application.

ONE-SPRAY METHOD.

One spray application by the trailer method at the time the grapes first touched in the clusters gave an average control of 83 per cent on Catawbas and 94 per cent on Concords as compared with 89 per cent control on Catawbas and 97 per cent on Concords when both the first and second sprays were given. This is a good showing for a "one-spray" schedule and this treatment might be the most efficient under some conditions. All results indicate that this one spray may be depended upon to save the crop from ruin by the berry moth.

In an effort to eliminate entirely the factor of spray residue on fruit for the basket market the spray application directly after grape bloom was tried alone. Data are insufficient on this treatment but indicate a marked effect on the final infestation. This treatment has the advantages of being the most important one for rootworm beetle control and of being timely to prevent black-rot infection of the young grapes. It may develop that this method will be practical after the infestation of the moth has been reduced by the use of the two-spray schedule for one or more years. Experiments on this point were conducted in several vineyards in 1918 but adjacent checks failed to show sufficient infestation to make results conclusive.

CONCLUSIONS FROM EXPERIMENTS.

The combinations of the first spray treatment with the second and of the first with the third gave satisfactory control. The third spray added to the first and second increased the effectiveness, but not enough to justify the expense of making the application. The second application alone averaged 83 per cent control and in all cases saved the commercial crop. The first application alone reduced the final infestation appreciably but needs further testing.

MATERIALS USED IN SPRAYS.

ARSENICALS.

ARSENATE OF LEAD, COMMERCIAL POWDER.

Arsenate of lead in powder form was used throughout this work. Since previous infestation had been extremely heavy in the experimental vineyards, the powder was used in 1916 at the rate of $2\frac{1}{2}$

pounds to 50 gallons, equivalent to 5 pounds of paste to 50 gallons, as a basis for comparison that year. The $1\frac{1}{2}$ -pound rate was used in but two vineyards in 1916. In 1917 the $2\frac{1}{2}$ -pound rate was retained in four vineyards and the $1\frac{1}{2}$ -pound used in seven. In 1918 comparison was made between 1 pound and $1\frac{1}{2}$ pounds of arsenate of lead powder.

TABLE VI.—*Relative efficiency of arsenate of lead at the rate of 1, $1\frac{1}{2}$, and $2\frac{1}{2}$ pounds (powder) to 50 gallons liquid.¹*

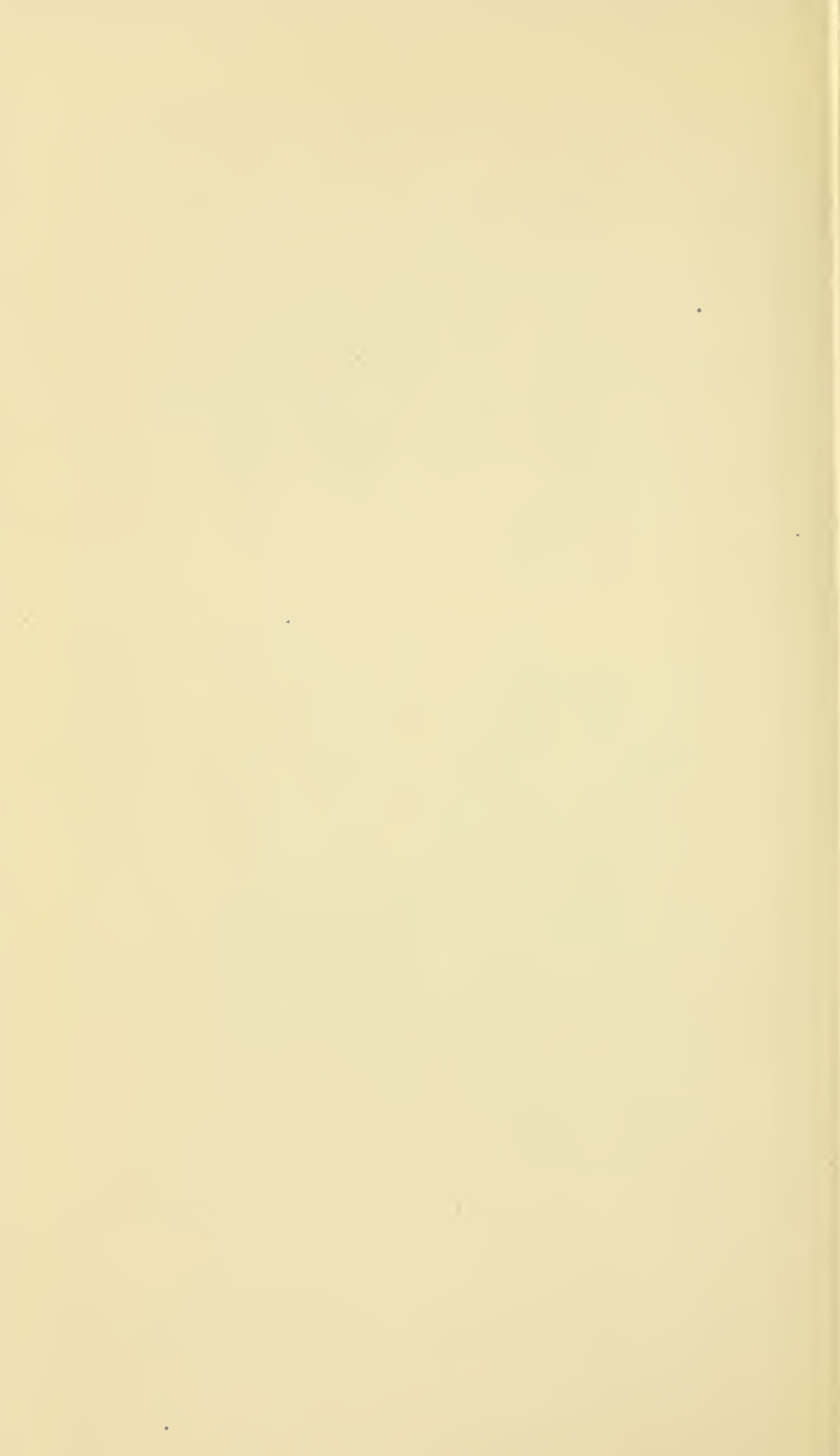
Pounds of arsenate lead powder to 50 gallons liquid	Spray applications.		Number of vineyards.	Number of plats.	Vineyard No.	Percentage of infested grape berries.					
	3 to 5 days after grape bloom.	When grapes touch in clusters.				Catawba variety.		Concord variety.		Ives variety.	
						Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.
SEASON 1916.											
1½.....	{ X X	X X	2	3	4 6	0.93 11.90	81.12 70.26	5.56	52.83	.....	.....
Averages.....			2	3	.....	6.42	75.69	5.56	52.83	.....	.....
2½.....	{ X X	X X	2	3	4 6	 10.41	 64.39	3.25 3.34	64.52 43.32	.....	.....
Averages.....			2	3	.....	10.41	64.39	3.30	53.92	.....	.....
SEASON 1917.											
1½.....	{ X X X X X X X	X X X X X X X	.....	.....	1 2 3 4 5 6 7	2.03 8.86 5.84 1.48	64.09 78.17 63.03 42.00	 0.47...........84 2.66	 61.61 32.11 20.60 88.03	0.43 2.94	20.14 19.59
Averages.....			7	10	.....	4.55	61.82	1.04	50.59	1.68	19.86
2½.....	{ X X X X	X X X X	.....	.....	1 2 4 6	.67 6.47 7.72	64.09 79.31 79.63	48	 30.14	 2.11	 39.67
Averages.....			4	5	.....	4.95	74.34	.48	30.14	2.11	39.67
SEASON 1918.											
1½.....	{ X X X X	X X X X	.....	.....	1 2 3 4	 4.78	68.02	 0.41 1.00	 2.54 6.28	0.86	7.85
Averages.....			4	4	.....	4.78	68.02	.71	4.41	.86	7.85
1.....	{ X X	X X	.....	.....	1 2	 7.39	 62.36	.....	.....	2.08	6.93
Averages.....			2	2	.....	7.39	62.36	.....	.....	2.08	6.93

¹ All plats received Bordeaux 2-3-50 and resin soap 1 pound to 50 gallons in 1917 and 1918. Same in 1916, except laundry soap 2 pounds to 50 gallons, first application; and second application vineyards Nos. 5 and 6.



SPRAYING AGAINST THE GRAPE-BERRY MOTH.

Comparative spreading qualities in spray mixture of a laundry soap (fig. 1) and a resin fish-oil soap (fig. 2).



The differences in the control effected by the various strengths of arsenate of lead were slight, as shown in Table VI. When comparing the averages the differences in the infestation of the adjoining checks should be kept in mind. The tests of 1 pound to 50 gallons have not been sufficient to justify one in drawing conclusions, but 1½ pounds to 50 gallons has proved adequate for control.

ARSENATE OF CALCIUM, COMMERCIAL POWDER.

Much interest has centered in the comparative merits of arsenate of calcium and arsenate of lead as insecticides. Arsenate of calcium has the advantage of being much cheaper than arsenate of lead, but doubt has prevailed as to its adhesive qualities and its effect on foliage. Since an extra spreader and adhesive in the form of resin soap is necessary even with arsenate of lead for spraying grape clusters, and since grape foliage is comparatively hardy to arsenicals, it was thought that arsenate of calcium should have a wide use in grape spraying.

TABLE VII.—*Relative efficiency of commercial arsenate of calcium and arsenate of lead for control of the grape-berry moth, Sandusky, Ohio, 1917, 1918. Both arsenicals applied in Bordeaux 2-3-50 with 1 pound of resin soap to each 50 gallons.*

Arsenical, pounds to 50 gallons.	Spray applications.		Number of vineyards.	Number of plats.	Vineyard No.	Percentage of infested grape berries.									
	3 to 5 days after grape bloom.	When grapes touch in clusters.				Catawba variety.		Concord variety.		Ives variety.					
						Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.	Sprayed plat.	Adjacent check.				
Arsenate of calcium commercial powder, 42 per cent As_2O_5 , 1 pound to 50 gallons.	X	X			1917.										
					1	9.46	64.09								
					4	13.78	79.63								
					5			0.58	32.11						
					6			.66	40.60	1.28	39.67				
					1918.										
					1					1.04	6.23				
					2	7.22	87.06								
					Averages.			6	7	10.15	76.93	.62	36.35	1.16	22.95
					Arsenate of lead commercial powder, 30 per cent As_2O_5	X	X			1917.					
1	2.03	64.09													
4	5.84	63.03													
5			.84	32.11											
6			.18	20.60						2.94	19.59				
1918.															
1										.86	7.85				
2	4.78	68.02													
Averages.			6	7						4.22	65.05	.51	26.35	1.90	13.72

Table VII shows the comparison of arsenate of calcium with arsenate of lead in six vineyards and seven plats. Control was

almost complete for both materials on the Ives and Concord varieties. On the Catawbas the arsenate of calcium averaged 90 per cent control and the arsenate of lead 96 per cent, but the checks adjacent to the arsenate of calcium plats were 12 per cent more heavily infested than those adjacent to the arsenate of lead plats so the comparisons are very close. These results may indicate that the arsenate of lead adhered slightly longer in the season than the arsenate of calcium. In recording the spray residue on the fruit at harvest time, slightly less was found on the arsenate of calcium plats than on corresponding arsenate of lead plats. This feature is an advantage in grape-berry moth spraying and is discussed later. No foliage injury that could be attributed to the arsenical occurred on any of the arsenate of calcium plats.

Grape spraying experiments were continued in 1919 and foliage injury occurred on all plats of the Ives variety where commercial arsenate of calcium was used at the rate of $1\frac{1}{2}$ pounds to 50 gallons of water with 3 pounds of freshly burned stone lime slaked and added to each 50 gallons of spray solution. This experience indicates that the use of arsenate of calcium on the Ives variety is unsafe.

ARSENATE OF CALCIUM, HOME-MADE PASTE.

Varied success had been reported from the use of home-made arsenate of calcium pastes as sprays for fruit trees. To determine the efficiency of these home-made materials for use in sprays on grapes the following experiments were conducted. Pastes were made according to the following formulas and methods and applied in spray solutions to grapes:

(1) Arsenate of soda + stone lime.

Sodium arsenate, fused (dry powdered)	60 per cent	
As ₂ O ₅ -----	ounces--	30
Stone lime-----	do----	18
Water-----	do----	48
Total-----	do----	96

The sodium arsenate was dissolved in the water and the resultant solution used to slake the lime. A smooth paste arsenate of calcium of about 18 per cent As₂O₅ content resulted. This was decanted 5 times to remove the sodium hydroxid. The resultant paste was used at the rate of $2\frac{1}{2}$ pounds to 50 gallons to be comparable with arsenate of lead (commercial powder 30 per cent As₂O₅), $1\frac{1}{2}$ pounds to 50 gallons.

(2) Arsenic acid + stone lime.

Arsenic acid (liquid) 78 per cent As ₂ O ₅ -----	ounces--	10
Stone lime-----	do----	8
Water-----	do----	34
Total-----	do----	52

The lime was slaked to a smooth paste with 18 ounces of water. The arsenic acid was diluted with the remaining 16 ounces of water and the diluted acid added to the lime paste a little at a time. The paste was stirred vigorously during the mixing. With each addition of acid the lime had a tendency to granulate, but continued stirring restored the smooth pasty condition. A sample of the final paste was analyzed by the United States Bureau of Chemistry under miscellaneous laboratory No. 24714 as follows:

Moisture.....	69.7
Total CaO (as received).....	15.08
Total As ₂ O ₅ (as received).....	12.04
Water soluble As ₂ O ₅	.02

5 grams samples in 1,000 c. c. CO₂ free water; equivalent to 2 pounds to 50 gallons. Free lime calculated as calcium hydroxid Ca(OH)₂ 4.4 per cent.

Paste made according to this formula was used on grapes in 1918 at the rate of 4 pounds to 50 gallons of water. Grape-berry moth infestation failed to develop in numbers sufficient for the desired comparisons in any one of the four vineyards in which these materials were used. The spreading qualities and effects on grape foliage, however, are important. The arsenicals were applied either in Bordeaux 2-2-50 or with stone lime 2 pounds to 50 gallons added to the mixture. In all cases resin fish-oil soap at the rate of 1 pound to 50 gallons was also added. The paste made from sodium arsenate spread equally as well as the commercial arsenate of calcium powder or arsenate of lead powder. The paste made from arsenic acid failed to spread as well and when dry it was not a smooth, even coating such as is desired. In no case could foliage injury be attributed directly to the use of either of the home-made arsenate of calcium pastes.

SPREADERS AND ADHESIVES.

Because of the partial failure of arsenate of lead and Bordeaux to spread over or "wet" the individual grapes in the grape clusters, various materials have been added to these to facilitate the spreading process.

The qualities desired in such a spreader are (1) quick-wetting power, (2) adhesive power when dry, and (3) that it be easily prepared for use. In addition, a material to be suitable must be compatible with Bordeaux mixture and arsenicals and also be comparatively cheap.

Former investigations¹ had shown that some form of soap was the most practical material for the purpose. When these investigations were undertaken various soaps were recommended by differ-

¹ Isely, Dwight, op. cit.

ent authorities. To determine the most efficient of these, experiments as shown in Table VIII were conducted in 1916.

TABLE VIII.—*Relative efficiency of different soaps as spreaders and adhesives, Schonhardt vineyard, Venice, Ohio, 1916.*

Kind of soap used.	Pounds in 50 gallons.	Spray materials combined with soaps.	Gallons spray material per plat second application.	Increase over resin soap.	Results in grape-berry moth control.				
					Number vines examined.	Number clusters examined.	Number grapes examined.	Infested grapes.	Variety.
				<i>Per ct.</i>				<i>Per ct.</i>	
Soft.....	2	(1)	140	86	14	790	18,960	17.04	Concords.
					10	342	12,996	24.83	Catawbas.
Laundry.....	2	(1)	100	33	11	608	14,592	6.78	Concords.
					10	198	7,524	6.11	Catawbas.
Resin fish-oil.....	1	(1)	75	0	12	735	17,640	8.50	Concords.
					10	311	11,918	8.37	Catawbas.
Checks.....					22	1,050	25,200	41.16	Concords.
					34	1,019	30,570	73.12	Catawbas.

¹ Bordeaux 3-3-50, arsenate of lead commercial powder 2½ pounds to 50 gallons.

Adjoining grape rows, each row including Concord and Catawba varieties, were sprayed three times during the season, the first application three to five days after grape bloom, June 27, the second when the grapes touched in the clusters, July 13, and the third at the beginning of the hatching period of second-brood larvæ, August 3. All spraying was done by the trailer method with medium disk angle nozzles and at a pressure of 150 pounds. The soaps were used as spreaders in mixtures of Bordeaux 3-3-50 and arsenate of lead powder 2½ pounds to 50 gallons. The season was unusually dry during July and August, favoring both adherence of spray materials and the development of the grape-berry moth. The Concords were harvested September 29 and the Catawbas October 10.

The soft soap used was a bulk product made especially for use in commercial laundries. This soap dissolved readily in hot water, but when applied to grapes formed in globules on the leaves and grape berries and dried in large drops. This condition was reflected in the percentages of infested grapes at harvest time, 17 per cent on Concords and 25 per cent on Catawbas. This increase in infestation on the Catawba variety did not occur with the laundry or resin soap, and so seems to indicate less adhesive power late in the season in the soft soap, since the Catawbas were harvested 12 days later than the Concords. The laundry soap used (Pl. IV, fig. 1) was the common yellow-bar soap, chipped and dissolved in hot water. This spread smoothly over the grape foliage and berries and gave a satisfactory covering when the spray was directed on the clusters for a sufficiently long time, but the amount required to "wet" them was 33 per cent greater than when the resin soap was used. When the third-spray application is used, as in this experiment, the adhesive

quality of the laundry soap appears equally as great as that of the resin. However, when the first and second sprays are applied and the third omitted, leaving a longer period between the last spray application and harvest time, it appears from field observations that the resin soap adheres longer than the laundry soap.

The resin fish-oil soap used was the commercial product obtained in bulk and of the consistency of thick molasses. This soap is readily dissolved in hot water and wets the clusters (Pl. IV, fig. 2) easily, as is indicated by the use of but 75 gallons as compared with 100 gallons of laundry soap solution and 140 of soft soap solution. The resin soap adhered the longest of any material tried. It was found that 1 pound of this soap to 50 gallons was about as efficient as 2 pounds of the other soaps and at the rate of 1 pound to 50 gallons is as cheap. No difference in compatibility with Bordeaux and arsenate of lead could be noted among the different soaps.

In conclusion it can be said that the resin fish-oil soap proved to have all the desired qualities of a spreader and adhesive and in the present state of knowledge appears the best spreader to use in grape spraying.¹

COMBINATION SPRAYS.

In the Sandusky and Lake Erie island sections where the Catawba variety predominates it is desirable to combine a fungicide for control of downy mildew, *Plasmophora viticola*, with the arsenical and soap for rootworm beetle and grape-berry moth control. In the other sections it is sometimes desirable to use the same combination for blackrot and insect control.

Bordeaux, either 2-2-50, 2-3-50, or 3-3-50, was used in combination with arsenate of lead powder $1\frac{1}{2}$ and $2\frac{1}{2}$ pounds to 50 with soaps at the rate of 1 and 2 pounds to 50. In some of the experiments the copper sulphate was omitted and stone lime, 2 pounds to 50 gallons, was used. The combining of the insecticide with the fungicide appeared to make no difference in insect control.

In some cases slight burning of Concord and Catawba foliage and serious burning of Ives foliage resulted from application of the Bordeaux-arsenate of lead-soap combination. The burning was most noticeable during the abnormally wet season of 1917. Experiments were conducted in 1918 to determine the material or combination causing the burning. The combinations of arsenate of lead and soap with Bordeaux proved responsible. Wherever the copper sulphate was omitted and the arsenate-soap-lime mixture was used, no injury resulted.

¹An appreciable difference was noticed in the length of time required to "wet" the clusters of different varieties. Beginning with Niagaras, which were most readily wet, the other varieties followed in about this order: Catawbas, Delawares, Ives, and Concorde. This difference is apparently closely correlated with the waxy bloom on the grape berries.

The burning was closely related to the thrift of vines, the stage of grape growth when sprays were applied, the weather during and following spray applications, and the method of mixing materials. Weak vines and those bearing too heavy crops were most seriously burned. Spray applications just before and after bloom caused more injury than later applications. Excessively wet and cloudy weather during and following spray applications appeared to increase burning. When either of the ingredients of Bordeaux was added to the other without being diluted, increased burning resulted.

From the above observations it is concluded that Bordeaux mixture should not be used in the arsenate of lead-soap combination on the Ives variety at any time and that in applying the combination with Bordeaux to Concord and Catawbas the above factors influencing foliage injury should be kept in mind. The arsenate of lead-soap-lime mixture was safe wherever used, even on the Ives variety. The injury from spray materials appears to be cumulative from season to season. The combinations of spray materials and factors influencing grape foliage injury warrant further experimentation.

DUSTING FOR CONTROL OF GRAPE-BERRY MOTH.

Much interest is centering in the application of insecticides and fungicides in dust form as compared with the liquid application. In an attempt to avoid all spray residue on grapes at harvest time, grape-dusting experiments were conducted in 1916, 1917, and 1918. The final infestation in check plats adjacent to the dusted plats was so light as to give inconclusive results except in 1916. The plan of the 1916 experiments and the results recorded are presented in Table IX.

TABLE IX.—*Dusting experiment for control of grape-berry moth, Schonhardt Vineyard, Venice, Ohio, 1916.*

Plat No.	Dust and spray mixtures used and dilutions.	Spray applications.		Counts of infested grapes at harvest, Oct. 13, 1916.					
		3 to 5 days after grapes bloom, June 29.	When second-brood larvæ begin to hatch, Aug. 4.	Number of vines examined.	Number of clusters examined.	Number of grapes examined.	Number of clusters infested.	Number of grapes infested.	Percentage of grapes infested.
1	Arsenate of lead powder, 2½ pounds to 50 gallons; Bordeaux, 3-3-50; laundry soap, 2 pounds to 50 gallons. Liquid application.	X							
	Dust mixture, arsenate of lead powder 10 per cent, hydrated lime 90 per cent.		X	8	211	6,330	211	2,978	47.04
2	Arsenate of lead powder, 2½ pounds to 50 gallons; Bordeaux, 3-3-50; laundry soap, 2 pounds to 50 gallons.								
		X	X	6	215	6,450	202	1,194	18.51
3	Check unsprayed.			8	239	7,170	239	5,668	79.05

The dust materials were applied with a small hand duster and the liquids with a gasoline power sprayer. In each case the application was made from either side of each row and a thorough covering of foliage and fruit effected. The dust materials adhered to the grape foliage fairly satisfactorily but did not adhere well to the smooth surface of the grape berries. No rain fell from the time of the application until August 11 when a light shower occurred. When the vines were examined on August 19 only a trace of the dust material was in evidence on the foliage or fruit, while the sprayed fruit was well covered with spray material. It required 40 pounds of dust material to dust 46 thrifty Catawba vines. At this rate and with the vines set 900 to the acre as is the practice in this section, it would require 783 pounds of material per acre. No doubt this would be materially reduced if a power machine were used for the dusting. If but half as much material were required per acre the amount of arsenical would be from 6 to 7 times as great as when applied in liquid form at the rate of $1\frac{1}{2}$ pounds of arsenate of lead powder to 50 gallons of spray and the liquid applied at the rate of 200 gallons per acre. The writers feel that the dust would have to be applied much more frequently than the liquid to be effective for berry moth control. This method of application might be satisfactory for treating small home grape arbors when applied frequently.

SPRAY RESIDUE ON GRAPES AT HARVEST TIME.

Throughout these investigations records were kept on the comparative amounts of spray residue on the grapes at harvest time. In all cases where the spray application shown as the third (fig. 1) was used in early August the fruit was heavily coated with spray material at harvest time. In nearly all cases where the combination of first and second sprays was used, and spraying completed by July 25, there was not sufficient spray residue at harvest time to affect the marketing of the grapes in baskets for table use. When either the first or second application was used alone the residue was lighter than when both were used. Slightly more residue resulted on the plats sprayed with arsenate of lead at the rate of $2\frac{1}{2}$ pounds than on those sprayed with the same material at the rate of $1\frac{1}{2}$ pounds to 50 gallons. No difference could be seen between the fruit from plats on which Bordeaux was included and those on which lime, 2 pounds to 50 gallons, was substituted for it. Slightly less residue was present on the plats sprayed with arsenate of calcium than on those sprayed with arsenate of lead where the comparison of material was on the basis of arsenical content. In one plat where these materials were mixed in the proportion of arsenate of calcium 9 ounces to arsenate of lead 5 ounces, the amount of residue was

greater than where arsenate of calcium was used alone and less than where arsenate of lead was used alone.

SUMMARY OF RESULTS WITH SPRAY MATERIALS.

Arsenicals.—Arsenate of lead powder at the rate of $1\frac{1}{2}$ pounds to 50 gallons proved adequate for commercial control of the grape-berry moth in the average case. Arsenate of calcium proved almost equally as efficient as arsenate of lead when compared on the basis of arsenical content and has the additional advantage of leaving less residue at harvest time.

Spreaders and adhesives.—Resin fish-oil soap at the rate of 1 pound to 50 gallons possessed all the qualities desired and required 33 per cent less spray material than laundry soap and 86 per cent less than soft soap, to wet the grape clusters on an equal area of vineyard.

Spray combinations.—The mixture of arsenate of lead and soap with Bordeaux should be used with care on Catawba and Concord varieties. The Bordeaux mixture should be omitted on the Ives variety. Stone lime at the rate of 2 pounds to 50 gallons should be added to the arsenate of lead-soap combination when Bordeaux mixture is omitted.

Dust mixtures.—The dust mixture of arsenate of lead and hydrated lime did not adhere to the grape clusters as well as the liquid sprays. The dust material was only partially effective for the control of the grape-berry moth.

Spray residues.—Objectionable residues do not result when the first and second spray applications are used with care. A spray application in August with the materials necessary for berry-moth control will leave a residue which will bar the fruit from the basket market.

COST OF TRAILER SPRAYING.

Because of the fan training system it was necessary, when spraying, to drive between each two rows of grapes. Each rodman sprayed but one side of one row at a time. In the Chautauqua-Erie belt it was found possible for a man to spray both sides of a row as he went, but there appears to be little gain in time by the latter method. In all of the experimental work it was found possible to mix and apply 6 tank loads of 150 gallons each or a total of 900 gallons in 9 working hours. This amount of material covered from 3 to 8 acres, depending on local conditions, and averaged about 5 acres. About one-half more material was required for the second application than for the first. Where the third application was made on plats that had received the second, the amount was about the same as for the

first application, but where the second had not been applied slightly more material was required for this third application than for the second application in adjoining plats. This difference is accounted for by the fact that the material from the second application remains on the grapes and overcomes the waxy bloom, thereby allowing quick wetting.

The following comparisons of single-nozzle, double-nozzle, and spray-guns for use in trailer spraying were made:

TABLE X.—*Experiments with single and double nozzles and spray guns for use in trailer spraying of grapes. E. Dunning's vineyard, Aron Lake, Ohio, 1918.*

[First spray application for grape-berry moth control, June 19.]

Plat No.	Number nozzles per rod.	Nozzle apertures.	Pressure per square inch.	Time to spray 150 gallons.	Number rows sprayed.	Percentage of time saved.	Percentage of material saved.
		<i>Inches.</i>	<i>Pounds.</i>	<i>Minutes.</i>			
1.....	1	$\frac{1}{8}$	175	64	14	0	0
2.....	2	$\frac{3}{16}$	175	50	16	21.8	14.2
3.....	(1)	$\frac{1}{8}$	200	38	16	40.6	14.2

¹ Spray guns, 1 to each hose line.

In Table X it is seen that two medium nozzles per rod saved 21 per cent in time and 14 per cent in materials as compared with one large nozzle. Spray guns saved 40 per cent in time and used no more material than two nozzles per rod, but an angle at the nozzle end of a rod is a necessity for thorough covering of the grape clusters. The writers believe that for the average vineyard two disk nozzles, at an angle of 45°, to each rod, with $\frac{1}{16}$ -inch apertures and a pressure of 175 pounds, will be found most satisfactory.

Materials and labor vary so greatly from season to season and in local sections that figures as to the cost of spraying are of little value. The statement can be made that an average of about 5 acres of thrifty vineyards can be sprayed by two men with a team in a day and will require from 100 to 250 gallons, averaging 147 gallons (Tables I and II) per acre for the first application, and from 160 to 300, with an average of 224 gallons per acre, for the second application.

CONCLUSIONS.

The grape-berry moth has been a more general pest in northern Ohio than in other commercial grape sections because of the following conditions: (1) Production of the late maturing Catawba variety, (2) cultural methods favorable to successful wintering of the insect, (3) harvesting methods which leave the insect in the vineyards, (4) a grape training system which prevents spray materials from reaching the clusters when applied with set nozzles.

Spray schedule.—The combination of first and second spray applications is adequate for control on the principal varieties of grapes grown in northern Ohio and when carefully applied leaves the fruit suitable for the basket market.

Spray materials.—A combination of arsenate of lead powder 1½ pounds to 50 gallons and resin fish-oil soap 1 pound to 50 gallons, in Bordeaux mixture or with stone lime 2 pounds to 50 gallons, may be used for spraying Concords and Catawbas. Copper sulphate should not be used in the above mixture for Ives variety. Arsenate of calcium, commercial powder, proved almost as efficient as arsenate of lead for grape-berry moth control. Dust mixtures do not adhere to the grape berries as well as liquid sprays but may be used on small home grape arbors if applied frequently.

Spray residues.—The grapes will be practically free from spray residue if the schedule recommended is used according to directions.

Spray method.—The trailer method only was used, and a trailer provided with a short rod and two angle nozzles proved most satisfactory in most vineyards.

RECOMMENDATIONS.

When possible, vineyards should be placed in condition for winter at the end of the cultivation season in July and left without further cultivation until spring; this practice is designed to increase the winter mortality of the grape-berry moth pupæ.

Number of spray applications.—For general practice for grape-berry moth control in northern Ohio two spray applications should be made.

Time.—The first application should begin 3 to 5 days after grapes set and the second should begin when the grapes touch in the clusters. This second application will usually come 3 to 4 weeks after the first.

Method.—Where the berry moth is a major pest the trailer method of spraying is the only one that will give complete control.

Materials.—Arsenate of lead, at the rate of 1½ pounds of powder or 3 pounds of paste to 50 gallons, as the active killing agent, with resin fish-oil soap, at the rate of 1 pound to 50 gallons, for a spreader and adhesive, used either in Bordeaux mixture or with 2 pounds of freshly slaked lime to each 50 gallons, has proved the most consistent combination tried. Bordeaux mixture should not be used on the Ives variety of grapes in northern Ohio because of the danger of injury to the foliage. Amounts of material should be great enough to allow the covering of all clusters with a thin, smooth film of spray material.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 838



Contribution from the Bureau of Entomology

L. O. HOWARD, Chief

Washington, D. C.

PROFESSIONAL PAPER

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CYPRESS BARK SCALE.¹

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ECONOMIC IMPORTANCE.

The Monterey cypress (*Cupressus macrocarpa* Hartw.) is one of the most popular shade and ornamental trees in California. It is planted separately or in hedgerows and often trimmed to formal shapes. Due to its thick, spreading habits it makes a good wind-break where it is planted in exposed areas. It is used especially along the coast and in the sandy citrus areas of San Bernardino County. It is also cultivated as an ornamental tree in many other parts of the world.

The cypress bark scale infests a large percentage of these trees in California, causing a great deal of injury, particularly to the thickly planted hedgerows (Pl. I, figs. 1, 2) and windbreaks. In the San Francisco Bay region it ranks first among the pests of the

¹ *Ehrhornia cupressi* (Ehrhorn). Order Hemiptera, suborder Homoptera, family Coccidae.

NOTE.—An investigation of the injury to cypress trees in California was taken up by the writer, at the suggestion of Dr. A. D. Hopkins, Forest Entomologist, in November, 1916. An examination made of these trees in the vicinity of the Los Gatos laboratory disclosed the main cause of the injury to be the cypress bark scale, *Ehrhornia cupressi* (Ehrhorn). This bulletin contains a record of studies of its history, biology, importance, and control made during this investigation.

The writer wishes to acknowledge the assistance of Dr. A. D. Hopkins, Forest Entomologist; Mr. H. E. Burke, Specialist in Forest Entomology; Prof. R. W. Doane and Mr. G. F. Ferris, of the Stanford University Department of Entomology; and Mr. George P. Gray, of the University of California Insecticide Laboratory, all of whom offered helpful suggestions during this study. Mr. R. D. Hartman assisted in the control experiments.

Monterey cypress. The insect is extremely difficult to control—a fact which makes it a very disagreeable and harmful pest.

HISTORY.

The cypress bark scale was first described in 1911 as *Sphaerococcus cupressi* by Mr. E. M. Ehrhorn¹ who collected it at Niles and San Jose, Calif., as early as 1903, and at Belvedere, Calif., in 1908, in the bark crevices of Monterey cypress. The next mention of this insect was in the report of the Selby Smelter Commission in 1915, when Mr. J. W. Blankinship² and Prof. R. W. Doane² reported it as one of the factors causing the death and dilapidation of the Monterey cypress in the Selby smoke zone. In October, 1918, Mr. G. F. Ferris,³ with the writer's approval, erected a new genus, *Ehrhornia*, for this species, for it certainly was not a *Sphaerococcus*. Although an important shade-tree pest, no discussion of this insect has appeared in print otherwise, except for a short note by the writer⁴ on its damage and distribution.

This coccid has no synonyms, having been listed under the name *Sphaerococcus cupressi* until the new genus, *Ehrhornia*, was erected in 1918, with *cupressi* as the type.

NATIVE HOST PLANT.

This scale insect could not be found at Cypress Point or Point Lobos, Calif., the only localities where the Monterey cypress is native, which showed quite conclusively that this tree was not the native host.

On November 9, 1917, the cypress bark scale was found infesting some planted trees of Arizona cypress (*Cupressus arizonica*) at San Jose, Calif., although it has not at the present writing been found on the native cypress in Arizona.

On December 6, 1917, this insect was found by the writer infesting one incense cedar (*Libocedrus decurrens*), and later several more trees, on the Stanford University campus. Later, the native incense cedars at Placerville, Calif., were examined. A number of them were found infested. They were several miles from any planted cypresses, which, moreover, were not infested.

Later, the cypress bark scale was found upon incense cedar at Ashland, Oreg., by Mr. Albert Wagner, of the United States Bureau of Entomology; at Crockers, Calif., by Mr. G. F. Ferris; and at

¹ EHRHORN, E. M. NEW COCCIDÆ WITH NOTES ON OTHER SPECIES. *In* Can. Ent., v. 43, no. 8, p. 275-280. (Figs. 3, 3a, b, c.) 1911.

² HOLMES, J. A., FRANKLIN, E. C., GOULD, R. A. REPORT OF THE SELBY SMELTER COMMISSION. U. S. Dept. Int., Bur. of Mines, Bul. 98, p. 381-597; 428-450. 1915.

³ FERRIS, G. F. NOTES ON COCCIDÆ II. *In* Can. Ent. v. 50, no. 10, p. 323-332. 1916.

⁴ MONTHLY LETTER OF THE BUREAU OF ENTOMOLOGY, U. S. Dept. Agr., no. 46, p. 5. February, 1918.

Stirling City and Giant Forest, Calif., by the writer. These localities are all from 75 to 150 miles apart and from 5 to 50 miles distant from any planted cypress. This seems to indicate that the incense cedar is the native host for this scale insect.

Mr. G. F. Ferris reports finding this scale insect upon herbarium specimens of Guadalupe cypress (*C. guadalupensis*) in the Stanford University herbarium, collected on Guadalupe Island, Mexico. It is impossible at present to state whether this is one of the native hosts of the scale, or whether the scale has been carried there from the mainland.

DISTRIBUTION AND SPREAD.

Incense cedar, the original host plant of the cypress bark scale, occurs in California, Oregon, western Nevada, and Lower California. The majority of these trees are found in the Sierra Nevada and northern coast range mountains of California, and in the Siskiyou, southern coast range, and Cascade Mountains of Oregon.

The cypress bark scale has been found at four widely separated points in the Sierra Nevadas (Stirling City, Placerville, Crockers, and Giant Forest, Calif.) and at one point in the Siskiyou Mountains (Ashland, Oreg.), which indicates that the scale undoubtedly occurs throughout the major portion of the range of the original host.

From this host the scale insect has spread to planted incense cedars and cypresses in the more thickly populated regions of the State. Two probable methods of distribution are suggested.

The cypress bark scale has been found to thrive on very young trees. Incense cedar seedlings occasionally are brought down from the Sierra Nevadas by tourists to plant in their own yards, and it is quite possible that the scale was carried to the valley on some of these trees. Rustic incense cedar is also transported from the Sierra Nevadas to be used quite extensively for pergolas and porch pillars. Ordinarily this would be done during the summer, which is the reproductive period for the scale insect. As the females can live for some time on green logs, it would be very easy for the young larvæ, hatched en route or after the logs have reached their destination, to attach themselves to near-by cypress trees, and thus start a heavy infestation in a new location.

From these original points of infestation the pest has spread through large areas. This has been accomplished for short distances by the usual agencies of wind, birds, insects, etc., and for longer distances by the shipment of infested nursery stock. The insect has been found by the writer infesting cypress seedlings in nurseries. Close planting of shade trees, hedges, and windbreaks undoubtedly aids in its rapid spread by natural means.

The scale insect, besides being distributed on the incense cedar, has now spread until it occurs on a large percentage of the cypress trees and hedges in almost every locality about San Francisco Bay, particularly on the San Francisco Peninsula, in the Santa Clara and Livermore Valleys, and north of the bay in Solano, Marin, and Sonoma Counties. It has been found in one locality, Riverside, in southern California, where a great many trees are planted for windbreaks. It is also to be found on Guadalupe Island, Mexico, as it was recently taken from herbarium specimens of Guadalupe cypress collected on this island.

The accompanying map (fig. 1) indicates the localities in which the cypress bark scale has been found to date, as well as the range of incense cedar and Monterey cypress. There are many localities within the range of cypress and incense cedar, which the writer has not yet visited, in which the scale insect will probably be found, when investigated. In all probability it eventually will infest all planted cypresses unless radical measures of control are adopted.

Since it has been found that the cypress bark scale can live on Arizona cypress, it is possible that it may spread to that host in Arizona and Mexico, or it may even be able to adapt itself to closely related hosts and spread throughout the country.

INJURY.

Injury to the tree is caused by the myriads of insects which are to be found in every crack and crevice of the trunk, branches, and twigs, each sucking out the plant juice through its long thread-like mouth parts. Under each scale may be found a small brown ring in the cambium, showing the tissue killed by each individual.

There is no secretion of honeydew, except for a small amount by the young larvæ, and only a slight formation of black sooty fungus about these insects, but a secretion of white cottony wax protruding from the bark crevices and covering the twigs gives abundant evidence of their presence (Pl. II).

First a limb or two on an infested cypress turns yellow, then red or brown, giving the tree (Pl. III) a scraggy appearance. This appearance often starts near the top of the tree and works down toward the center, or perhaps spreads from one limb to the rest until the whole tree is dead. Quite often the trees are dug up or felled before this final stage is reached; others are left to mar the landscape until they rot and fall.

In hedges, yellow and red spots appear, which increase finally to large proportions, leaving wide gaps of dead material which eventually destroy the beauty of whole hedges. One hedge in Livermore, nearly a half mile long, was infested and dead or dying

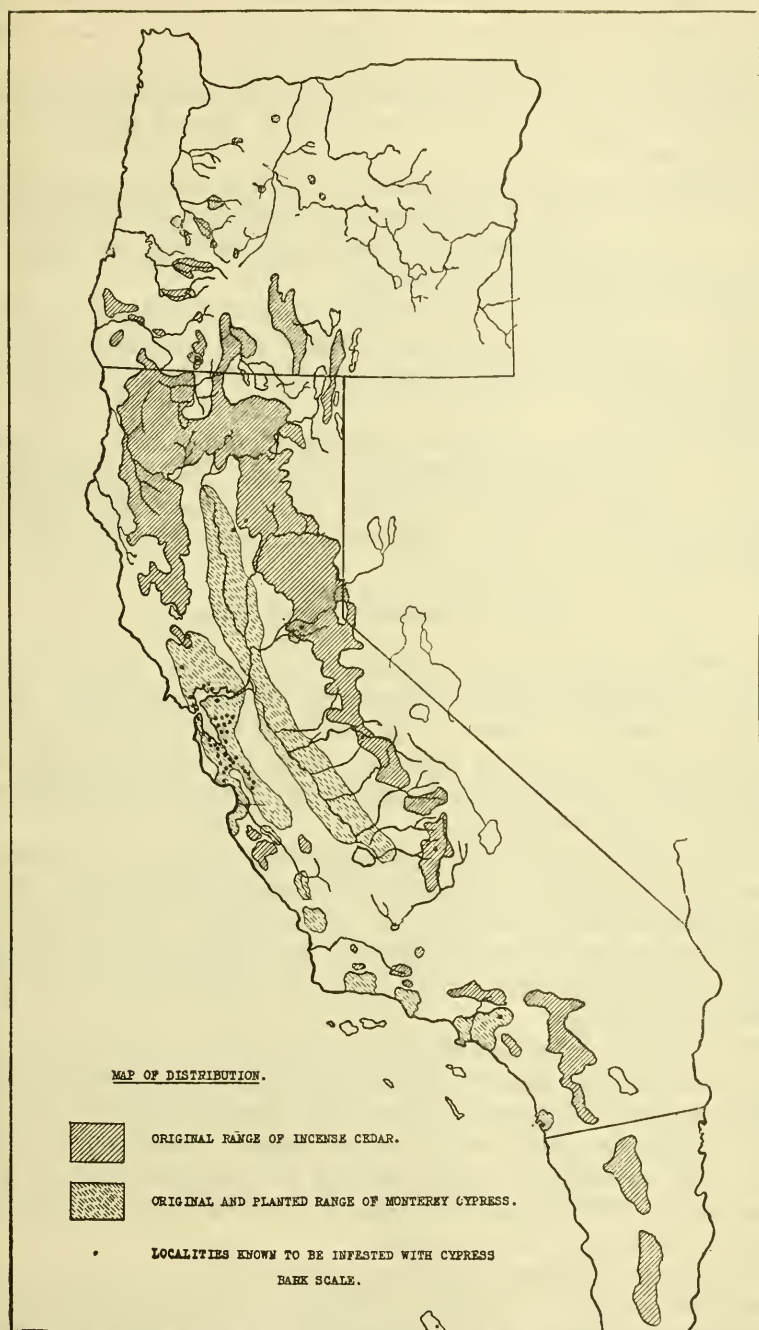


FIG. 1.—Map of distribution of the cypress bark scale.

for its full length. Young hedges but 3 or 4 years old have been found infested and some of the trees dead even before the hedge has become of any particular use or ornament.

Windbreaks with an opening here and there, caused by the death of a tree or group of trees, are not nearly as efficient as they would be otherwise.

In the drier regions of the State the injury is more apparent than in the fog belt, where the tree seems to be much more thrifty. In the former regions the cypress is not a long-lived tree, and when infested death is hastened considerably.

Trees occasionally are found that are heavily infested, yet quite normal in appearance. It is believed that such trees have only recently been infested, and will eventually show the effects of this slow-working insect.

In some localities in central California there is hardly a respectable row of trees or hedge left to greet the eye. At Los Gatos many trees have died and very few remain which are not now infested. About San Jose, Livermore, Benicia, etc., there are also heavy infestations.

INJURY IN THE SELBY SMOKE ZONE.

The "Selby smoke zone" is an area extending for nearly 10 miles along the Carquinez Strait, between San Pablo and Suisun Bays. The Selby smelter is located on the south side and at the west end of this strait. The prevailing winds are from the west and southwest, thus blowing the smelter smoke across the strait onto the territory between Vallejo and Benicia.

In this area there has been considerable complaint of damage done to different trees and plants by this smoke. Many of the Monterey cypresses in this territory are dead or dying. Examination of these trees and plants by specialists of the Selby Smelter Commission has proved that insects and fungi are responsible for part, at least, of the damage.

The writer has examined Monterey cypresses in certain parts of the smoke zone and has found the scale insect abundant. In the Benicia Cemetery, practically 100 per cent of the trees were found infested and a large percentage were dead or dying. According to Prof. Doane, this cemetery, although infested in 1913, contained but few dying trees. Probably at that time the infestation was rather recent, but has gained headway since.

In the writer's judgment, the cypress bark scale is the main factor causing the unsightly and dying condition of these trees. One need only see the condition of the cypresses in the Livermore and Santa Clara Valleys to reach this conclusion.

ASSOCIATED INSECTS.

The cypress bark scale is by no means the only enemy of the cypress. The cypress barkbeetles (*Phloeosinus cupressi* Hopk. and *P. cristatus* Lec.) are important primary insects, causing the death of a considerable number of trees, and perhaps ranking first among the pests of the cypress in California, considering the State as a whole. In the San Francisco Bay region they must, however, take a place second to the scale in point of damage done.

Many people throughout the State have considered the beetles as the only enemies of the cypress, and, when noting the death of a tree, have taken it for granted that the beetles were the primary cause, without bothering to investigate properly. The entire foliage of trees killed by the beetles turns first yellow, then brown, and is much more conspicuous than the foliage of a tree being killed by inches by the scale insect. The presence of the beetles is also more easily detected.

At times the beetles have been found working independently of other insects, and killing trees. For example, at San Carlos, on the San Francisco Peninsula, the beetles have been killing several trees per year for a number of years. In the spring of 1918 they were found entering the green trunks of live trees and girdling them. Other trees showing the work of *Phloeosinus*, dead one or two years, stood near by. The recently attacked and the unattacked trees were apparently very healthy.

The beetles are often secondary pests, entering trees well infested and weakened by the scale insect. At Martinez, Calif., in January, 1918, a row of 12 trees was heavily infested with the scale insect. Three of these had been recently killed by barkbeetles. On Alum Rock Avenue, San Jose, Calif., there is a long double row of cypresses, all of which are heavily infested with the cypress bark scale and practically all of which have a sickly appearance. Here the barkbeetles attack an occasional tree, or a section thereof, and hasten its death. They also impair the beauty of the trees by entering into the center of small twigs and weakening them, so that the wind breaks them off. When gathered together, the twigs from one tree formed a pile 2½ feet high and nearly as broad. There were also many twigs still hanging broken in the tree. The injury to cypresses by these beetles will be treated separately in a later paper.

Three species of mealybugs, *Pseudococcus ryani* Coq., *P. sequoiae* (Coleman), and *P. cupressiculus* Ferris, also infest cypresses and occasionally do some damage.

Other associated scale insects are *Xylococcus macrocarpae* Coleman, *Lecanium corni* Bouché, *Diaspis carueli* Targ., *Aspidiotus*

hederæ (Vallot), and *Aspidiotus ehrhorni* Coleman. None of these have been noted doing any considerable damage.

Still other associated insects of various orders are: *Phymatodes nitidus* Lec., *Atimia confusa* Say, *Trachykele blondeli* Mars., the cypress moth (*Argyresthia cupressella* Wals.), the cypress cone-borer (*Cydia cupressana* Kear.), a horn-tail wasp (*Sirex californicus* Ashm.), the arborvitæ plant-louse (*Lachniella tujafilina* Del Guer.), and an undetermined tussock moth.

FOOD PLANTS.

The known food plants of the cypress bark scale are: Monterey cypress (*Cupressus macrocarpa* Hartw.), Arizona cypress (*C. arizonica* Greene), Guadalupe cypress (*C. guadalupensis* Wats.), and incense cedar (*Libocedrus decurrens* Torr.). On one other tree, a deodar cedar (*Cedrus deodara* Loud.), at Santa Rosa, Calif., a dead male was found in its cocoon.

It seems strange that the scale insect should not occur on all species of cypress if it will infest two trees as different as Monterey cypress and incense cedar, yet Italian and Oriental cypresses, two varieties of *Cupressus sempervirens*, are immune to the attack of this insect. They have been found in many instances in close proximity to infested Monterey cypresses and entirely free from the scale insect. In one case, in the Benicia Cemetery, 27 cypresses formed a square about a plot. Two-thirds of these were Monterey cypresses, with every third tree an Italian cypress, touching a Monterey cypress on each side. Every Monterey cypress was infested and dead or dying, while not a scale could be found on the Italian cypresses.

Specimens of Himalayan cypress (*C. torulosa* Don.), Macnab cypress (*C. macnabiana* Murray), funeral cypress (*C. funebris* Endl.), Sargent cypress (*C. sargentii* Jepson), and Port Orford cedar (*Chamaecyparis lawsoniana* (Murr.) Parl.) have been examined, although not in large numbers, within the infested areas, and no cypress bark scales could be found upon them.

DESCRIPTION.¹

THE EGG.

Egg (Pl. IV, A), immediately after being deposited, regularly oval, smooth, and shiny, of a transparent pale yellow color, with eyes of embryo visible through membrane as two dark spots near one end. Average length of seven eggs 0.34; mm.; width 0.14.

LARVA.

FIRST INSTAR.

Young larvæ (Pl. IV, B) of both sexes alike. Pale yellow in color, with long, flat, oval bodies 0.43 mm. in length, 0.20 mm. in width. Antennæ (Pl. V,

¹ The following detailed description of all stages from the egg to adult, both male and female, were made from living and freshly mounted material collected during the study of the cypress bark scale.



FIG. 1.—A TALL MONTEREY CYPRESS HEDGE, SHOWING MANY DEAD SPOTS
CAUSED BY THE CYPRESS BARK SCALE.

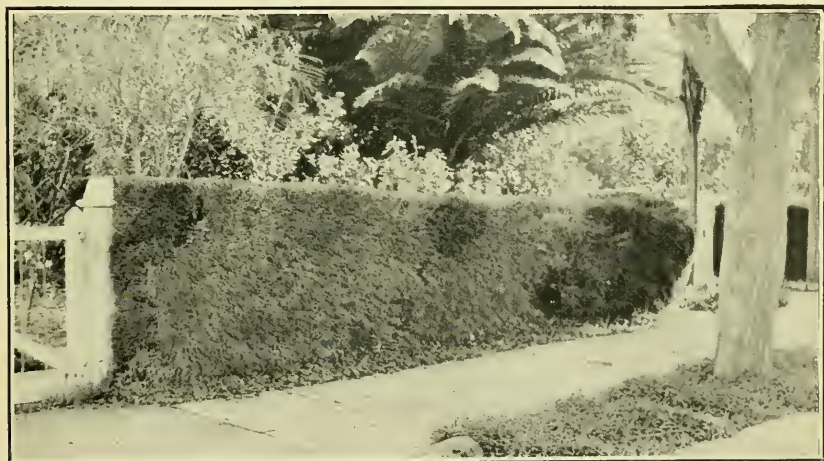


FIG. 2.—A MONTEREY CYPRESS HEDGE KILLED BY THE CYPRESS BARK SCALE.
THE CYPRESS BARK SCALE.



FIG. 1.—CHARACTERISTIC INFESTATION ON MONTEREY CYPRESS TWIG, SHOWING THE COTTONY EXCRETIONS OF THE CYPRESS BARK SCALE. $\times 0.4$.



FIG. 2.—CHARACTERISTIC INFESTATION ON THE BARK, THE COTTONY EXCRETIONS OF THE CYPRESS BARK SCALE PROTRUDING FROM THE CREVICES. $\times 2$.

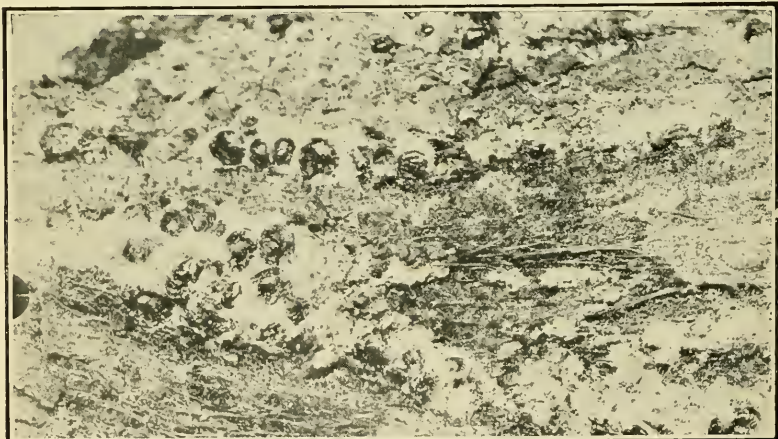


FIG. 3.—THE DRY OUTER PORTIONS OF THE BARK REMOVED, REVEALING THE FEMALES OF THE CYPRESS BARK SCALE UNDERNEATH. $\times 4$.

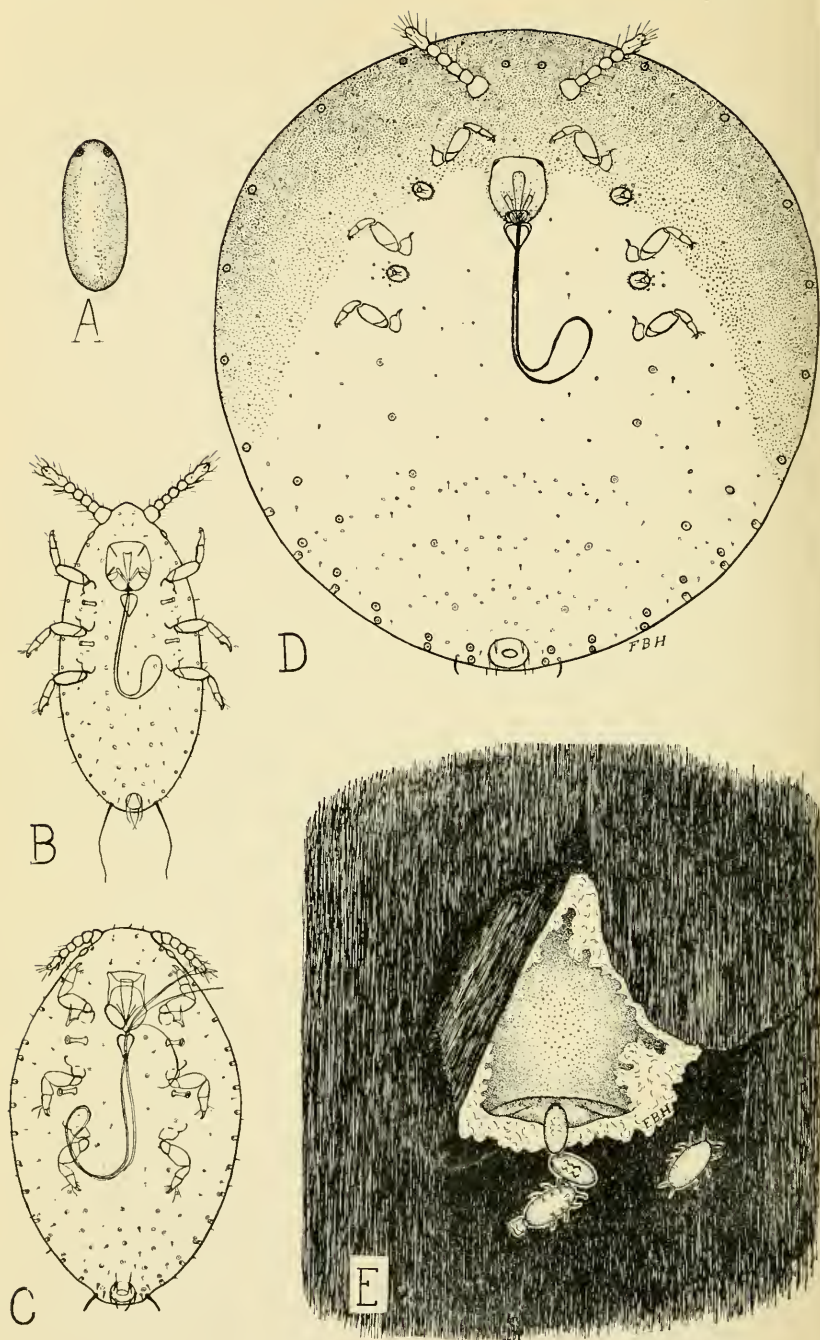


FIG. 1.—A MONTEREY CYPRESS WHICH IS NEARLY DEAD FROM THE WORK OF THE CYPRESS BARK SCALE.



FIG. 2.—A ROW OF MONTEREY CYPRESSES, ALL OF WHICH ARE PRACTICALLY DEAD FROM A CYPRESS BARK SCALE INFESTATION.

THE CYPRESS BARK SCALE.



THE CYPRESS BARK SCALE.

A, Egg ($\times 55$); B, larva, first instar ($\times 85$); C, female larva, second instar ($\times 55$); D, adult female ($\times 55$); E, portion of bark removed, showing adult female depositing eggs, the eggs hatching, and the larva crawling away.

A, 2) six-segmented, first segment broadest, sixth longest. Normal antennal formula as follows: 6, 1, (2, 4, 3, 5). Joints 2, 3, 4, 5 subequal and variable, thus causing various formulæ. Antennæ rather hairy. Fifth segment bearing one broad spine, while four occur on sixth segment. Eyes marginal, set a short distance behind antennæ. Legs rather short and stout. Tarsus slightly longer than tibia, the two combined slightly longer than femur and trochanter combined. Legs rather hairy, tarsi bearing four knobbed digitules. Usual coccid sucking mouthparts present. About 26 trilocular pores set rather regularly about margin and two longitudinal rows of the same type on dorsum of insect. Caudal setæ (Pl. V, B, 1) prominent, rather stout, and about $140\ \mu$ long; borne on small inconspicuous anal lobes. Anal ring bearing six setæ, noticeably longer than in later stages. A number of short spines scattered over body.

SECOND INSTAR.

Immediately after the first molt some differences between the sexes can be detected under the microscope. Toward the end of the second stage an external difference can be observed in the shape, the female being broader than the male.

Female larva (Pl. IV, C) about 0.84 mm. long and 0.51 mm. wide, oval in outline, yellowish brown in color. Legs and eyes similar to those of first-stage larva. Antennæ very similar except that sixth segment bears only two broad spines. Caudal setæ (Pl. V, B, 3) much shorter, being only $37\ \mu$ long. Anal ring still bearing six hairs, also shorter than in preceding stage. A larger number of tubular wax ducts, varying from 40 to 75, to be found on dorsum, particularly abdomen, and on lateral margin. Also a number of trilocular pores and small spines scattered over body.

Male larva (Pl. VI, A) about the same length but narrower than female; 0.85 mm. long by 0.43 mm. wide. Color yellowish. Caudal setæ twice as long as those of female, half as long as those of first-instar larva, $75\ \mu$. Six anal hairs, in length equaling diameter of anal ring; longer than those of second-stage female, but shorter than those of first-stage larva. Pores of male larva very inconspicuous (Pl. V, D, 2), smaller than those of female. Small quinquelocular type pores scattered over both dorsum and venter of body. Small tubular ducts found mostly on margin. Small spines also present.

ADULT FEMALE, THIRD INSTAR.

Body (Pl. IV, D) nearly circular and quite convex, the width exceeding the depth and the length exceeding the width. Average length 1.45 mm., average width 1.35 mm. General color reddish brown. Anterior half of body quite heavily chitinized, particularly on margin. Derm smooth.

Antennæ (Pl. V, A, 3) no longer marginal, but occurring on ventral side of body, six-segmented, slightly longer, averaging $144\ \mu$, but similar to those of second-instar larva, bearing only two of the four spines found on sixth segment of first-instar larva. As in larva antennal formula varying considerably, of practically no value. Average formula as follows: 6, 1, 3, (5, 2, 4). Eyes lacking.

Legs (Pl. V, C, 1) short and stout. Tibia and tarsus (Pl. V, C, 2) subequal, being together slightly shorter than trochanter and femur combined. Leg bearing a few hairs and tarsus bearing four knobbed digitules. Usual coccid mouthparts present. Large tubular ducts (Pl. V, D, 1) occurring on margin and dorsum of body. Small trilocular pores and fine spines scattered over body, particularly on abdomen. Anal ring (Pl. V, B, 4) occurring on ventral side of body, small, simple, and with six small setæ or hairs. A pair of small caudal setæ one on each side of anus. Anal lobes absent.

MALE PREPUPA.

With the second molt, the male larva assumes the form of a partly developed pupa, called the prepupa (Pl. VI, *B*). Form elongate oval; length 0.93 mm., width 0.50 mm. Color pale glassy brown, eyes black. Antennae short, reaching to base of anterior legs and now indistinctly 10 segmented. Wing pads very short, curving under body to middle pair of legs. Anterior legs reaching forward, covering "face," the two posterior pairs lying against abdomen. Mouth parts wanting. Segmentation of thorax indistinct. Prepupa incapable of movement, except in abdominal segments and anterior legs, which may be feebly moved.

MALE PUPA.

With the third molt, the male becomes a true pupa (Pl. VI, *C*), greatly resembling the adult male, except for the lack of anal wax filaments, and the possession of wing pads instead of wings. General color light brown, head and large, conspicuous wing pads paler, legs and antennae glassy white, eyes black. Antennae distinctly 10-segmented and longer, reaching to base of middle pair of legs. Wing pads appressed to sides of body and extending posteriorly to second abdominal segment. Legs capable of some movement, anterior pair extending beyond the head; middle femora placed transverse to and extending beyond lateral margin of body, rear pair inclining posteriorly. The larval eyes have disappeared, and have been replaced by one dorsal and one ventral pair. Mouth parts replaced by an approximate pair of eyes. Length 0.95 mm.; width 0.45 mm.

ADULT MALE.

(Pl. VI, *D*, *E*.)

Measurements of average adult male: Length of body (exclusive of appendages) 0.75 mm.; antennae 0.55 mm.; wax filaments 0.93 mm.; wing expanse 2.15 mm. General color light brown with paler brown appendages.

Antennae (Pl. V, *A*, 1) 10-segmented, rather hairy, first joint short and broad, second rather long and broad, others more slender. Antennal formula: 3, 4, 5, 6, 7, 8, 9 (10, 2), 1. Legs rather long, slender, and somewhat hairy. Wings transparent white, slightly iridescent and pubescent. A veinlike thickening, beginning at base of wing, branching near base, one branch paralleling costal margin, the other extending toward anal distal margin. Club-shaped halteres each bearing a hook, which catches in a pocket on anal margin of wing. Abdomen terminating in a short blunt style. Two long white wax filaments arising one on either side of base of style, and extending posteriorly. Each filament arising from a number of pores which surround base of two long slender setae. Setae enveloped by wax filaments.

SUMMARY.

As will be noted from the foregoing descriptions, there are three instars (excluding the egg) in the female. These all have legs, which are not used after the larva is attached. All stages are found in crevices or under some covering on the bark and are nearly or completely concealed by the enveloping cottony wax. Newly hatched first-instar larvæ may be found crawling actively over the bark before attachment.

There are five stages in the male. The first two stages are found in similar positions, but the second stage after becoming full grown re-

moves to a dry, secluded spot, where it spins a cocoon in which the remaining transformations take place.

Size and shape are of some use in distinguishing the different stages. The female in its second stage is considerably broader than the male in the second stage, while both are larger than in the first stage. The adult female is more circular than in the preceding stage.

The antennæ of the adult female are slightly longer than the antennæ of second-stage larvæ, while the latter are slightly longer than those of the first-stage larvæ. All are very similar, however, the only distinguishing character being that the first-stage larva possesses two more broad spines on the sixth segment.

The three pairs of legs on each individual are alike, nor is there any difference between the larvæ and the adult female, except a very slight one in the relative lengths of the femur, tibia, and tarsus. Mr. Ehrhorn's figures indicate a difference in the arrangement of the hairs and digitules, which the writer has been unable to detect. There is a very small, scarcely discernible, tooth or "denticle" on the face of the claw in all these stages.

The caudal setæ give good characters for the separation of the different stages. On the first-stage larva they are about 140 microns long; on the second-stage male they are about half as long, 75 microns; those of the second-stage female half as long as the latter, 37 microns; and those of the adult female very much shorter still. The length of the setæ on the anal ring also decreases in the same ratio.

Simple marginal eyes are present in all the larval stages, but not in the adult female. Mouth parts are present in all stages, except in the male prepupa, pupa, and adult.

Four spiracles are present in all the larvæ and the adult female, one behind each of the four forward legs. In the larvæ they appear as simple tubes, and more as large chitinized circles in the adult female.

There are several types of pores found on the derm of the scale insect, which aid in distinguishing the different stages. The small sessile pores are of two types, viz., "trilocular" (Pl. V, *D*, 4) and "quinelocular" (Pl. V, *D*, 5). The former are more or less triangular and contain three cells or loculi. The quinelocular pores are nearly circular, but tend to be five-sided, containing ordinarily six loculi, one in the center with five clustered about it. Aside from these there are circular pores communicating with internal ducts. These are short and tubular, bearing at the inner end a cup-shaped depression. All types are presumably capable of secreting wax.

The first-stage larva bears only small pores of the trilocular type. These are arranged in a marginal row on each side of the body and in two longitudinal rows on the dorsum.

On the second-stage female larva are to be found the small trilocular pores scattered over the body, and from 40 to 75 of the large tubular ducts on the margin and dorsum (particularly on the abdomen). The pores of the second-stage male larva are of two types: The small quinquelocular type which are found all over the body, and tubular ducts similar to those of the second-stage female larva, but much smaller and less conspicuous, found mostly on the margin.

The pores and ducts of the adult female are of the trilocular and tubular types, the first scattered over the body and the latter occurring on the margin and dorsum of the body, much the same as in the second-stage female larva.

Small spines (Pl. V, *D*, 3) are present on all these stages. Viewed from above, these spines are likely to have the appearance of circular pores, but can be soon distinguished by altering the focus of the microscope.

LIFE HISTORY AND HABITS.

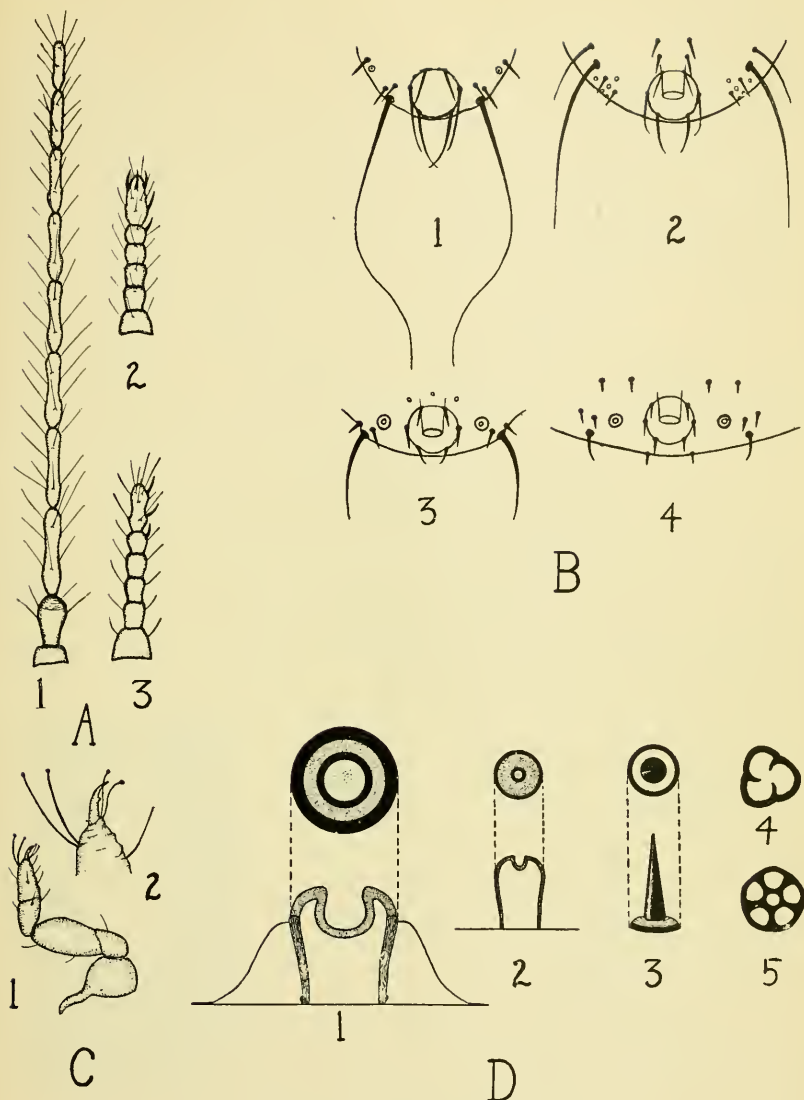
In the early winter adult females are found containing a few eggs. The eggs increase in number and by early spring from 30 to over 100 may be found within each female. During this time the females have increased considerably in size and have become quite heavily chitinized on the anterior half of the body.

OVIPOSITION.

The embryos in the eggs develop within the body of the female until they are about ready to hatch, when they are expelled (Pl. IV, *E*). The female is well surrounded by a cottony secretion, but when oviposition is begun the tip of the abdomen is drawn in, leaving a space in which the eggs may remain until hatched. After hatching, the larvæ are usually able to find an exit between the cotton and the surrounding bark.

Each female is capable of laying 50 to 100 or more eggs. The greatest number of eggs that has been found within a female at any one time is 105. The eggs are laid slowly, covering a long period of time. They are laid during the warmer part of the day at intervals of 7 to 70 minutes. After laying a series of 5 to 10 eggs, the female ceases oviposition for a day or so and then resumes it.

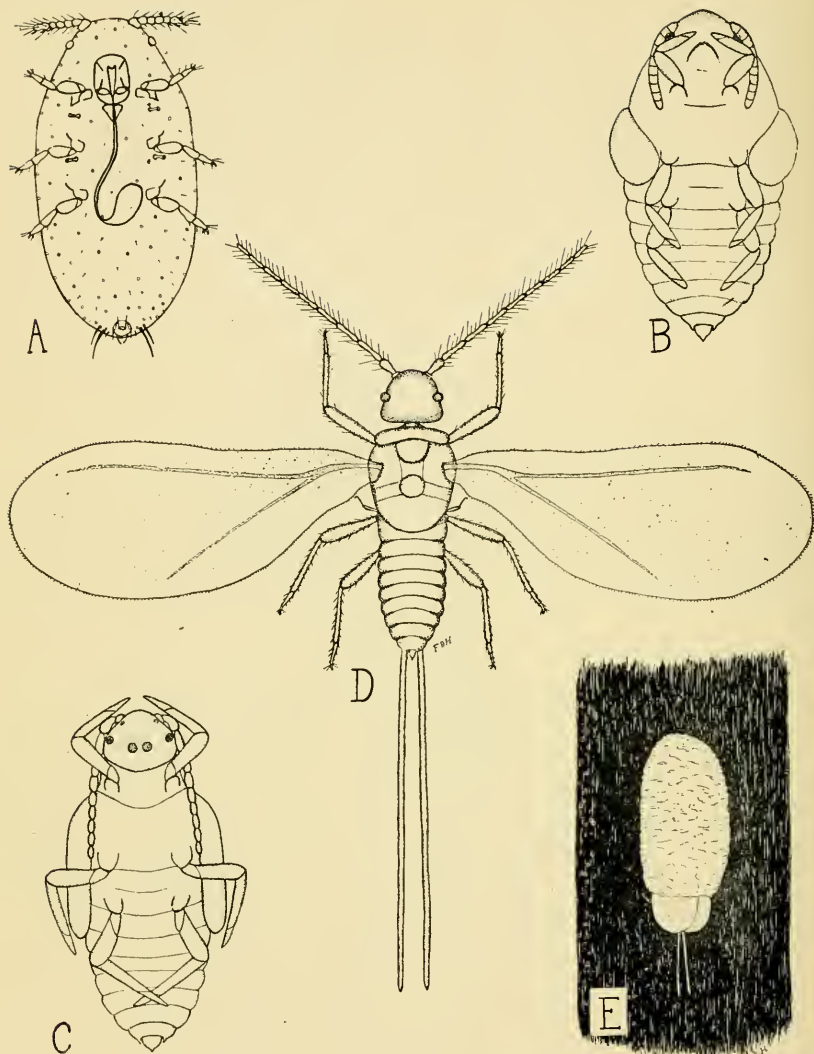
Most of the embryos in the eggs are deposited tail first, about one-sixth being deposited head first. The head end of the embryo is evidenced by the two black eyes which are visible through the egg membrane. By a series of contractions of the abdomen, the egg is forced out until entirely free from the body of the adult. These eggs are oblong oval when first deposited, but flatten out somewhat before the rupturing of the membrane occurs.



THE CYPRESS BARK SCALE.

A, Antennae: 1, adult male; 2, first-stage larva; 3, adult female (same as second-stage larva);

B, Tip of abdomen, showing anal rings and caudal setae: 1, first-stage larva; 2, second-stage male; 3, second-stage female; 4, adult female; *C*: 1, leg of adult female; 2, tip of tarsus and claw; *D*, Ducts and pores: 1, large pore and tubular duct of adult female; 2, small pore and tubular duct of second-stage male; 3, spine; 4, trilocular pore; 5, quinquelocular pore.



THE CYPRESS BARK SCALE.

A, Male larva, second instar ($\times 50$) (male and female first-instar larvae are identical); B, male prepupa ($\times 50$); C, male pupa ($\times 50$); D, male adult ($\times 50$); E, male adult ready to emerge from cocoon.

About 15 minutes after the eggs are deposited, the embryo starts a series of convulsions and after considerable struggling ruptures the membrane inclosing it. The ruptured membrane is pushed down over the abdomen and the larva, which is usually on its back, begins waving its legs about in the air. It usually takes this larva 20 to 30 minutes to free itself from the membrane, and after exercising its legs for 30 or 40 minutes it finally gets to its feet and crawls away (Pl. IV, *E*). The larva quite often is stuck to the next expelled egg and may be held out in space for some time, but the struggles of one or the other finally allow the feet of the larva to touch foundation, where it soon makes use of them.

MIGRATION.

The larvæ become very active soon after exclusion and begin searching for a suitable spot upon which to locate. The majority of them immediately work down into the bark crevices or under the cottony secretions of the parent females, where they become attached. Some seem more fastidious than others and travel farther in search of newer feeding grounds. Recently hatched larvæ when placed upon favorable young trees do not travel far, and usually settle down after investigating two or three crevices in the bark.

Larvæ placed upon paper were able to travel considerable distances. (See fig. 2.) The average rate of travel for six larvæ was 54.25 cm. per hour, which they were able to maintain for several hours. The greatest distance traveled by one larva was 174 cm. in two hours. One larva, after traveling 124.46 cm. in four hours, apparently put its last efforts into trying to pierce the paper with its proboscis. Table I gives the time, distance, and rate per hour traveled by six cypress bark scale larvæ on black paper for the first few hours of their migration. Black paper was used in order to facilitate following the tiny pale larvæ in their wanderings. When white paper was used the larvæ were soon lost. There seemed to be a slight phototropism in the case of most larvæ, the majority of them finally wandering toward the light.

TABLE I.—Record of travel of six first-instar larvæ of the cypress bark scale on rather smooth black paper.

No.	Time.	Distance.	Rate per hour.
	<i>Hours.</i>	<i>Cm.</i>	<i>Cm.</i>
1	1.5	109.22	72.81
2	2.5	143.51	57.40
3	4.0	124.46	31.11
4	2.0	173.99	86.99
5	2.0	142.24	71.12
6	2.0	66.04	33.02
Average.	2.333	126.577	54.255

Larvæ isolated in vials, immediately after hatching, lived for two and three days. Living for this length of time and traveling at the above rate of speed during only the warmer parts of the day, larvæ could go considerable distances in search of proper food. In this way larvæ are able to migrate from one tree to another in closely planted hedges or windbreaks. During this migratory period, larvæ are also likely to be transported short distances by dropping from high



FIG. 2.—Tracings of five first-instar larvæ of the cypress bark scale during migration. Reduced $5\frac{1}{2}$ times. All were started from the same center.

branches and being carried by the wind, and for longer distances by animate agencies, such as insects, birds, and animals.

ATTACHMENT.

As soon as a larva finds a suitable crevice or a protected area in the bark, it thrusts its proboscis into the bark tissues, where it remains permanently. Larvæ have not been known to remove themselves from this first location to another after once becoming attached. Larvæ which have become detached somewhat later in life are able to crawl about feebly, but finally die without being able to attach

themselves again. Although the legs are retained throughout the full lifetime, they are of no further use to the female larva except to aid in removing the cast skins when molting.

Larvæ will attach themselves on twigs as small as one-fourth inch in diameter and on trunks a foot or more in diameter, provided the bark is not too thick to be pierced with their proboscides. A few scale insects have been found infesting the smooth trunk of seedlings less than one-half inch in diameter, but rough bark is essential to a heavy infestation. The deeper the larvæ are able to go into the crevices the more satisfied they appear to be. They have been found so well secreted in crevices that it would seem there was no room left for their future growth, and much less any chance of mating, particularly after being enveloped with a white flocculent secretion.

LARVA.

FIRST INSTAR.

Immediately after attachment the larva begins enveloping itself with this white cotton until entirely hidden from view. A drop of honeydew, resembling pitch, is emitted by some larvæ, especially on vigorous trees, during the first few weeks after attachment.

Growth starts immediately after attachment and is practically constant throughout the whole instar. The larva at the end of the instar is very similar to those just hatched, except that the former are larger, somewhat broader in proportion to their length, and slightly darker in color.

At the end of the first instar, the larva molts, the skin being pushed down off the tip of the abdomen. From 40 to 44 days were required to complete the first instar in the few cases observed.

SECOND INSTAR.

There is very little development during the second stage. The female larva secretes more waxy cotton and changes in size and shape until it resembles the adult female. After a period of from one to two months the second molt occurs and the larva becomes an immature adult.

The male larva increases in size and becomes yellowish white in color. It takes on a firmer and trimmer appearance. After a slightly shorter time than that required by the female larva, the male larva detaches itself and crawls about in search of a favorable place in which to pupate. It may pick a spot under some cotton or in a curl of the outer bark. Cocoons have also been found in the cast skins of coccinellid larvæ and in the ruptured bodies of dead female scale insects.

Here the male larva proceeds to spin a cocoon, secreting cottony wax from the small ducts which occur on both the dorsum and venter of the body, turning over and over in the operation. The cotton secreted is finer than that secreted by the female larva, as would be expected because of the smaller ducts on the male.

It requires three or four days to complete the cocoon. After a day or two of inactivity, the larva molts to a prepupa, pushing the cast skin out through a slit which is in the rear end of the cocoon.

MALE PREPUPA AND PUPA.

The male from now on is without mouth parts, and during this dormant period is an inactive creature, capable only of feebly waving its front legs and wriggling its abdomen when disturbed.

The male remains in this stage from 10 to 15 days, and with this molt becomes a true pupa, greatly resembling the adult male. As in the previous stage, the pupa is inactive. Normally the same length of time is required for this stage as for the previous one. A few pupæ have been found hibernating in the colder Sierras.

ADULT.

MALE.

When the pupal skin is cast, the male's wings are extended to their full size and then folded, one over the other, upon its back. As soon as the wax filaments have grown to their full length, which requires from 30 minutes to several hours, the male backs out of the cocoon and becomes very active. It immediately begins searching for a mate. The length of life of the male is never more than one or two days and death occurs very soon after mating.

FEMALE.

The color of the female becomes darker after the second and last molt, and upon becoming heavily chitinized is a dark reddish brown. After mating the body increases considerably in size, becoming nearly globular. Inside the female's body may be found a large number of eggs in different stages of development. The body still is covered quite thoroughly with cotton and deeply hidden in the bark crevices. Upon becoming an adult a new supply of coarser threads of wax is excreted. After depositing the eggs, an act which covers a considerable period of time, the female shrivels and dies, nothing but the chitinized skin remaining. If the host plant is still alive, this vacancy is soon filled by a female of the next generation.

SEASONAL HISTORY.

(Fig. 3.)

There is but one generation per year, the limits of which are not very definite. The males appear in the fall, being most abundant in

October and November. These mate and die in a few days. At this time most of the females have cast their last skin and are about one-half grown.

The winter is passed as adult females, with no very definite period of hibernation in the lower altitudes. In the Sierra Nevadas there is a more definite period of hibernation and the generations are more even. The female larvæ become adults somewhat earlier in the fall. When the cold weather strikes them, development becomes very slow. In December females are found containing a few eggs. These develop during the winter and early spring.

Oviposition begins on the first warm days of spring and lasts throughout the summer, beginning about April 1 and terminating the latter part of September. In the fall the females, having com-

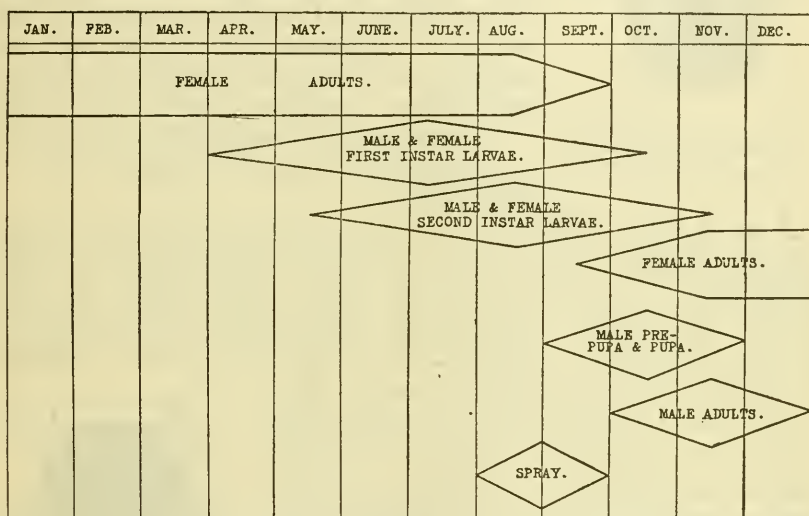


FIG. 3.—Seasonal history diagram of the cypress bark scale.

pleted oviposition, shrivel and die. By this time the young females of the next generation are quite well developed, thus assuring the presence of adult females during the whole year.

The larvæ issue from the eggs 30 or 40 minutes after deposition and soon attach themselves. Larvæ of the first instar may be found from April to the middle of October, second-instar larvæ from the middle of May to the middle of November, and adult females from about September 15 to the following September. Male prepupæ and pupæ may be found in September, October, and November, and adults in October, November, and December. A male pupa was found hibernating in the Sierra Nevadas. A few scattering first and second stage larvæ may be found during the winter in the milder climate near the coast.

PREDACIOUS AND PARASITIC ENEMIES.

There are several coccinellids which aid in the control of the cypress bark scale. None of them is aggressive enough, however, to affect its abundance very materially.

A very small ladybird, *Nipus biplagiatus* Casey (fig. 4), is the most abundant and widespread enemy of the scale. This is a sturdy little beetle, about 1.3 mm. in length, brownish black, with a lighter amber spot in the center of each elytron. It is generally present wherever the scale insect is to be found. On one side of a cypress limb in a space $3\frac{1}{2}$ by 24 inches (84 square inches), there were found 46 specimens of this coccinellid and in certain parts of this area there were as many as four beetles to the square inch. There were undoubtedly still more out of sight under the bark scales. Very few of the larvæ of this beetle were seen but this may be accounted for by their extremely small size and their pale brown color.

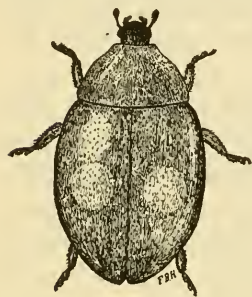


FIG. 4.—*Nipus biplagiatus*, a coccinellid enemy of the cypress bark scale. $\times 25$.

A small black nitidulid beetle, *Cybocephalus californicus* Horn (fig. 5), is very abundant and is sometimes confused with the above coccinellid. It is, however, slightly smaller, shiny black, with more delicate legs, and of a more compact globose form. This beetle has not been seen actually feeding upon the scale insect, yet it is believed to be an aggressive predacious enemy. It is always found about the scale insect, and often with its head in the bark crevices as if feeding upon the scale insect. The larva of this beetle is small and white and not easily found.

The twice-stabbed ladybird, *Chilocorus bi-vulnerus* Muls., is an abundant and aggressive predator upon the cypress bark scale. This beetle is often found upon cypress, feeding upon this insect pest.

The common black-spotted red ladybird, *Hippodamia convergens* Guérin, has been found a few times feeding upon the scale. As this beetle breeds in great numbers in the Sierra Nevadas, it probably feeds upon the scale on incense cedar in its native haunt.

Larvæ of the common brown lacewing, *Symphorobius angustus* Banks, are often found feeding upon the cypress bark scale and aiding materially in retarding its increase and spread.

A few specimens of a small hymenopterous parasite have been reared from caged material of this scale insect. It can not, however,



FIG. 5.—*Cybocephalus californicus*, a nitidulid beetle always found about the cypress bark scale. $\times 25$.

be considered as of any importance, because of its great scarcity. In all the writer's observations but three scale insects have been found with punctures in them, from which parasites have escaped. Two of them were from Monterey cypress and one from incense cedar in the Sierra Nevadas. The scarcity of this scale insect in the Sierras would indicate that a parasite was quite active upon it. If such is the case, it has not as yet been noted.

CONTROL EXPERIMENTS.

A series of experiments was undertaken in order to find one or more materials capable of reducing the numbers of this very harmful pest. Only those sprays were experimented with which would be able to penetrate well into the crevices of the bark, where many of the scales were located. Oil sprays are the only ones which meet these requirements, consequently no others were tried. The oil sprays are capable of penetrating and creeping into all the tiny cracks and crevices of the bark when properly applied. The higher the gravity of oil used, the better is the penetration.

First, crude-oil emulsion was used, but, being a low-gravity oil, it was unsatisfactory. Next, distillate emulsion was used and, being of somewhat higher gravity, was more satisfactory, but still did not kill more than 40 per cent of the scale insects. Miscible oil No. 1 was next used, being of about 28° Baumé gravity. This used in a 12½ per cent solution was quite satisfactory, destroying from 75 to 90 per cent of the scale insects. A well-known washing powder was tried as an emulsifier with both the emulsion and the miscible oil, but proved of no value, so its use was discontinued.

Carbolic sheep dip was tried out, as this was reported to have very good penetrating powers. This, however, gave only about 30 per cent efficiency and was not used further. Six per cent was the highest used with this, as a higher percentage was believed to be dangerous to the tree. It also made the lungs of the experimenter quite sore.

Next, miscible oil No. 2 was experimented with, for this had the very high gravity of 33° Baumé. A 12½ per cent solution of this proved quite satisfactory, killing a high percentage of the scales and upon second application destroying virtually 100 per cent. Further experiments with this substantiated these results.

In Table II are recorded all spraying experiments performed upon the cypress bark scale. All spraying was done in the warm part of the day, generally in the afternoon, when the trees were dry. The spray was applied very heavily and thoroughly, every part sprayed being completely drenched. In experiments Nos. 19, 20, and 21 (small trees) the entire tree was sprayed; in all others only the trunk, lower limbs, and foliage were sprayed, as the trees were too large to be treated with a hand pump. The cypress foliage

appears to be very resistant, for no burning occurred at any time from the application of the spray.

It was discovered that the small larvæ were much more easily killed than the adult females. All larvæ could not be killed with one spraying, however, on account of the long period of hatching. The last of the brood were not hatched by the time the first were becoming adults; consequently two sprayings were necessary, one to exterminate the early hatched larvæ, the other to exterminate those hatched later.

TABLE II.—*Record of spraying experiments performed upon the cypress bark scale.*

No.	Date.	Formula.	Number of trees.	Per cent of efficiency.	Remarks.
1	1918, Feb. 25	Crude-oil emulsion, 7½ per cent.....	6	0	In shade.
2	Mar. 9	Distillate emulsion, 3 per cent.....	3	0	Rained that night and following 3 days.
3	...do.....	Distillate emulsion, 5 per cent.....	5	0	Do.
4	Mar. 28	Distillate emulsion, 6 per cent.....	4	25	In shade.
5	Apr. 10	Distillate emulsion, 7½ per cent.....	3	20	Warm, dry.
6	...do.....	Distillate emulsion, 7½ per cent, and washing powder, 1 pound to 20 gals.	3	20	Do.
7	Apr. 24	Distillate emulsion, 12 per cent.....	2	40	Do.
8	June 4	Carbolic sheep dip, 3 per cent.....	3	30	Hot, dry.
9	July 18	Carbolic sheep dip, 6 per cent.....	2	30	Do.
10	Mar. 28	Miscible oil No. 1, 6 per cent.....	4	25	Warm, in shade.
11	Mar. 29	Miscible oil No. 1, 6 per cent, and washing powder, 1 to 20.	3	40	Warm, dry.
12	Apr. 24	Miscible oil No. 1, 12½ per cent.....	2	75	Do.
13	...do.....	Miscible oil No. 1, 12½ per cent, and washing powder, 1 to 20.	2	40	Do.
14	Oct. 7	Miscible oil No. 1, 12½ per cent.....	2	90	Warm, dry; repeat on No. 12.
15	...do.....	Miscible oil No. 1, 8 per cent.....	2	75	Warm, dry; repeat on No. 11.
16	July 18	Miscible oil No. 2, 12½ per cent.....	2	75	Warm, dry; killed 50 per cent adults and 99 per cent larvæ.
17	Oct. 7	do.....	1	75	Warm, dry; rained 2 days ago.
18	...do.....	do.....	1	100	Rained 2 days ago; repeat on 1 tree No. 16.
19	Oct. 26	do.....	38	80	Hedge of young trees.
20	Oct. 28	do.....	39	80	Do.
21	...do.....	do.....	1	85	Repeat on tree No. 38 of Experiment No. 19.

In experiments Nos. 1 to 7, percentages are of actual oil content, not emulsion content.

RECOMMENDATIONS FOR CONTROL.

The following measures are recommended for the control of the scale insect.

Cut out all dying trees or limbs of trees beyond saving and destroy them in order to reduce all possible sources of infestation.

Purchase clean nursery stock for planting. If the stock is infested, return it to the nursery and demand clean stock to replace it.

Most fruit growers now realize that spraying is necessary for the maintenance of healthy trees and the production of clean fruit. Most people, however, still believe that a shade tree should always be able

to take care of itself. One can not hope to maintain healthful, vigorous, shade and ornamental trees without proper care and occasional spraying.

Infested trees should be sprayed twice in the fall, once in August or the first part of September and again in the latter part of September. This is to kill the larvæ before they become mature. The proper dates to spray may vary slightly in different localities and with different seasons, in which case certain phenological events may be relied upon. The first spraying should be done when the fruit of the French prune (the common variety planted throughout the State) becomes blue or first begins to fall from the tree. The second spraying should be done from one to two weeks after the last prunes have been harvested. If but one application is attempted, spray in the middle of September or when the maximum number of prunes are falling from the trees, as this would be the best time to kill the greatest number of larvæ.

The only satisfactory material to be used is a $12\frac{1}{2}$ per cent solution of a high gravity miscible oil (33° Baumé). The proportions are as follows:

	Part.
Miscible oil (33° Baumé)-----	1
Water-----	7

Put the requisite amount of oil in the pail or barrel to be used and add about one-fifth that amount of water. After some stirring this will become a thick creamy liquid, whereupon the remaining amount of water may be added with constant stirring. This should be continually agitated while being applied.

The ordinary barrel or bucket pump will serve very well in applying the spray to small trees. A good power apparatus, however, is necessary in order to compel the spray to reach to the top of large trees or to penetrate through the heavy foliage of thick hedges.

Thoroughness of the application can not be overemphasized. It is absolutely necessary for successful control. See that the spray comes in contact with every twig and that all the larger limbs and trunks are thoroughly drenched.

When planting trees not intended for trimmed hedges or wind-breaks, leave a wide space between each individual. It is a common fault to plant all sorts of trees too closely. Cypressess planted purely for ornament should be fully 40 or 50 feet apart. Trees already planted can be thinned out to this distance. This will retard the spread of the insect and give more nourishment to each tree left. The addition of fertilizers and water about the base of infested trees will also aid in overcoming the effects of the scale insect.

In badly infested regions it is not advisable to replant cypresses. There are many other species of trees which are less prone to infestation and are just as ornamental, which should be planted. There are other trees and plants, also, which make effective trimmed hedges.

The common privet (*Ligustrum vulgare* Linn.) forms an admirable hedge. The holly-leaf cherry (*Prunus ilicifolia* Walp.), *Atriplex canescens* James, and *Pittosporum* spp. also are recommended. *Pittosporum*, however, is subject to attacks from scale insects which are just as difficult to control as the cypress bark scale. The Oriental and Italian cypresses form quite effective coniferous hedges, the latter being tall and slender. Certain forms of red cedar (*Juniperus virginiana* Linn.) are used as trimmed hedges in certain sections of the United States. If this proves to be immune to the scale insect, it should be a very good substitute for the Monterey cypress.

SUMMARY.

The main cause of the browning and death of so many cypress trees, hedges, and windbreaks throughout California is the cypress bark scale, *Ehrhornia cupressi*.

It was found in the course of a thorough investigation that the scale insect was not a native of the Monterey cypress, but of the incense cedar which occurs in the mountains of California, Nevada, and southern Oregon. From this host it has probably spread to the Monterey cypress by the transportation of incense-cedar seedlings or rustic timber to the regions infested.

The characteristic injury caused by this insect begins to show on one or two limbs and slowly spreads to the rest of the tree. The foliage turns first yellow, then red or brown, giving the tree a very dilapidated appearance. After a few years the whole tree dies.

The food plants of the cypress bark scale are Monterey cypress, Arizona cypress, Guadalupe cypress, and incense cedar.

The larvæ are small oval bodies, pale yellow in color, which are active for a short time after hatching. They attach themselves in crevices of the bark and are soon enveloped in a white cottony secretion. As they reach maturity they become reddish-brown in color and nearly spherical in shape.

Oviposition begins in the spring and lasts throughout the summer. The eggs hatch into larvæ in less than an hour and soon attach themselves. The females reach maturity in the fall and hibernate over the winter, starting oviposition in the spring. The males appear in the late fall or early winter to mate and die.

There are several insects which prey upon the cypress bark scale, none of which, however, is abundant enough to control the scale insect. Consequently remedial measures have to be adopted. A 12½ per cent solution of a high-gravity miscible oil is the spray recommended. To obtain complete control it is necessary to spray twice in the early fall, once in August and once in the latter part of September.

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THE WESTERN GRASS-STEM SAWFLY

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INTRODUCTION

The western grass-stem sawfly (*Cephus cinctus* Norton) (fig. 1) is in many ways one of the most interesting and important insects that has attracted the especial attention of economic entomologists in recent years. It is a species native to the United States and has been gradually coming into prominence since the beginning of the present century by reason of the change which the feeding habits of the larvæ have been undergoing subsequent to its discovery. Originally a grass feeder, it is becoming a serious menace to the grain growers of the Northwestern States because of its acquired appetite for small grains, within the stems of which it now subsists.

Such changes of diet are probably occurring everywhere with greater frequency than formerly was deemed possible, especially among the phytophagous insects of the Middle West. When given a

¹ The writer wishes to express his appreciation of the assistance afforded by Messrs. J. C. Crawford, A. B. Gahan, and S. A. Rohwer, of the Bureau of Entomology, in the preparation of this paper, the two former in determining parasitic material reared during the progress of the studies of the sawfly, the latter in making a critical examination of a large series of sawfly individuals reared or collected from various parts of North America, and for furnishing detailed descriptions of *Cephus cinctus* besides a key to the North American species of the genus *Cephus*. Helpful criticisms from these men have added to the value and accuracy of the paper.

The writer desires also to mention the valuable assistance and cordial cooperation of Mr. Norman Criddle, entomological field officer for Manitoba, Canada; of Mr. A. P. Henderson, of Bottineau, N. Dak., and of the several county agents in the infested areas, who have aided in various ways in the accumulation of information and material.

chance to feed upon the various cultivated plants grown in bulk by the farmer or gardener, many of these insects gradually desert their native host plants and to a greater or less degree change their habits, including in their fare the more succulent and easily found food.

HISTORY

The existence of the western grass-stem sawfly was first made known in 1890 when Mr. Albert Koebele reared adults from larvæ that were mining in the stems of native grasses growing in the vicinity of Alameda, Calif.¹ During the next year, 1891, the species was described under the name of *Cephus occidentalis* by Messrs. Riley and Marlatt, from a series of individuals reared by Mr. Koebele and also

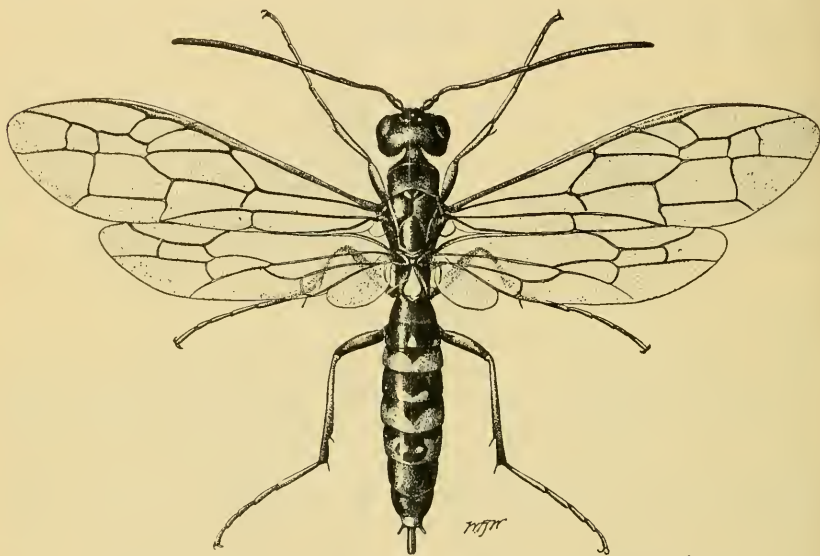


FIG. 1.—Western grass-stem sawfly (*Cephus cinctus*): Adult female. Much enlarged.

from cotypes that had in the meantime been collected in Nevada and Montana.² In connection with this description the prophetic suggestion was made that: "The economic importance of this species arises from the fact that it may be expected at any time to abandon its natural food-plant in favor of the small grains, on which it can doubtless successfully develop."

Nothing more was heard of this sawfly until 1895, when the late Dr. James Fletcher, Entomologist to the Dominion of Canada, swept adults at Indian Head, Northwest Territories, on July 5. He believed it to belong to the European species, *Cephus pygmaeus* L., and under

¹ Koebele, A. Notes. In U. S. Dept. Agr. Div. Ent. Insect Life, v. 3, p. 71, 1890.

² Riley, C. V., and Marlatt, C. L. Wheat and Grass Saw-Flies. In U. S. Dept. Agr. Div. Ent. Insect Life, v. 4, p. 168-179, 1891. (See p. 177-178.)

this name it was mentioned in his report for 1896¹ with the further statement that wheat straws containing *Cephus* larvæ had been sent in by Mr. John Wenman of Souris, Manitoba, who stated that the injury done by them was very slight. Nevertheless the prophecy of five years before had been fulfilled, since these grass feeders actually had attacked small grain.

In 1902 Dr. Fletcher reported, in a private letter, that he had found the larvæ numerous in grasses in the Northwest. In 1905 and 1906 Mr. G. I. Reeves, an agent of the Bureau of Entomology, noted the work of the larvæ in various grasses, chiefly *Agropyron* sp., in Wyoming and the Dakotas, and in 1906 the same observer found the larvæ attacking wheat sparingly near Kulm, N. Dak.

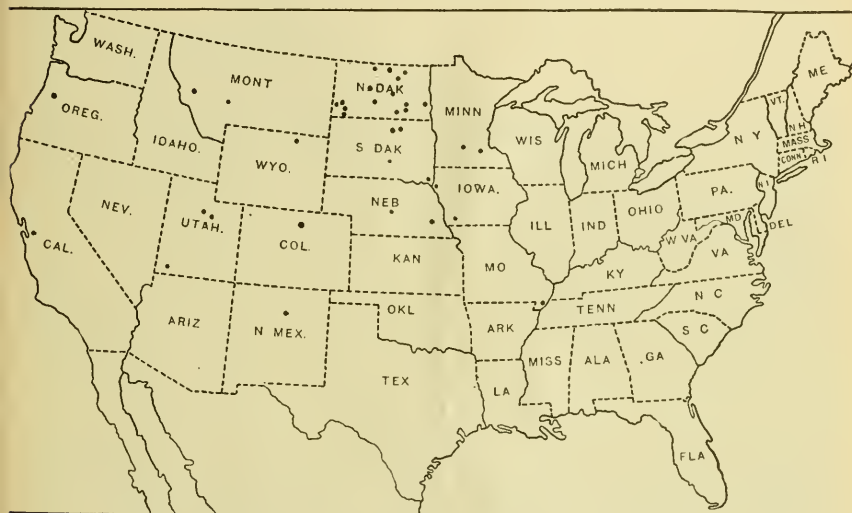


FIG. 2.—Distribution of the western grass-stem sawfly in the United States.

August 31, 1907, Mr. E. O. G. Kelly, then an agent of this bureau, noted a few wheat straws near Minot, N. Dak., that had been burrowed by the larvæ of *Cephus*.

In 1908 Messrs. F. M. Webster and G. I. Reeves found the larvæ of *Cephus* working in grasses in the Willamette Valley in Oregon. In the same year Dr. Fletcher again called attention to this insect, stating that in the previous autumn it had appeared in central Manitoba and in the southeastern part of Saskatchewan in much more serious numbers than ever before, and that the quantity of broken straws in the fields was causing the farmers some alarm. Mr. Norman Criddle of Aweme, Manitoba, a close observer and practical farmer, wrote to Dr. Fletcher that this fly had increased considerably during the last year or two, and was turning its attention to wheat and rye.

¹ Fletcher, J. Report of the Entomologist and Botanist, 1896. Can. Dept. Agr. Exp. Farm, 1897. (See p. 229-230.)

August 20, 1909, Prof. H. B. Penhallow reported from Sherwood, N. Dak., that he had examined about a hundred fields from Minot, N. Dak., north to the boundary line and several miles into Canada and had found larvæ present in every field but one. He estimated the damage in these fields as ranging from 5 to 25 per cent of the crop, but spoke of one field about 27 miles east of Sherwood where the damage was said to have exceeded 66 per cent. R. W. Sharpe reported similar damage in the Red River Valley, near Fargo, N. Dak.

During 1911 and 1912 the writer found the species occurring freely in the native grasses in various parts of Utah, and as occasion offered



FIG. 3.—Plants of *Elymus condensatus* growing along the railroad right of way. The natural habitat of the western grass-stem sawfly in Utah.

the life history of *Cephus* was learned. Most of the facts in this paper are the result of this study. (Fig. 3.)

During the years 1913, 1914, and 1915 the writer has found this sawfly almost universally distributed over the Dakotas, Minnesota, Iowa, and Nebraska, feeding in *Elymus*, timothy, and *Agropyron* at Elk Point, S. Dak., in *Agropyron tenerum* near Chamberlain, S. Dak., in timothy at Edgeley, N. Dak., in *Bromus inermis* near Merricourt, N. Dak., in *Elymus canadensis* at Shakopee, Minn., in practically all these grasses near Sioux City, Iowa, and in wheat, timothy, and *Elymus* near Minot, N. Dak. It seems to have little choice in the various native grasses and is ready to attack any of the cultivated

sorts provided the stem is sufficiently large for the larval gallery. As a rule, the larger, more robust stems are chosen for attack, especially in cultivated grasses such as timothy and *Bromus*. Blue grass and similar slender-stemmed species appear to be immune. It is a little surprising that a minute examination of *Stipa viridula* from New Mexico developed the fact that none of the stems of this robust grass were infested. This *Stipa* was gathered in northern New Mexico, growing in almost the same latitude as the *Elymus condensatus* near Pinto, Utah, where the fly abounds.

August 25, 1916, the writer, then at Pierre, S. Dak., received instructions from the Bureau of Entomology to visit Bottineau County



FIG. 4.—Wheat field of Thomas Yeam, near Souris, N. Dak., showing heavy damage done by the western grass-stem sawfly in 1916.

in North Dakota and investigate injury to wheat. It was believed locally that the Hessian fly was responsible for the damage that was being done. A very superficial examination of the injured fields proved beyond a doubt that the *Cephus* was present in large numbers and was doing an immense amount of mischief. Every field was infested, not only in Bottineau County, but in the adjoining counties of Benson, Pierce, McHenry, and Rolette. Near Souris, a few miles south of the Canada line, a large field of wheat on the farm of Thomas Yeam was fairly carpeted with the "straw-fallen" grain. (See figs. 4 and 5.) The loss from *Cephus* injury in this field was estimated at 60 per cent or more. Six feet of drill row here were taken at random and examined plant by plant. Forty-eight infested stubs were found,

an average of eight to each foot of drill row. This would mean 150 to the square yard or about 726,000 larvæ to the acre. Higher counts were made later in this same field, so the average may be larger than stated. During April, 1917, Mr. Yeam's field was again visited and a random square yard marked out and counted. Two hundred and sixty-nine infested stubs were taken from this yard, which would mean more than 1,300,000 larvæ to the acre. Fifty of these stubs were opened and 47 of the imprisoned larvæ that had spent the winter within the straw were found to be normal and very much alive. The proportion of living individuals among the hibernating larvæ seldom falls below this ratio.

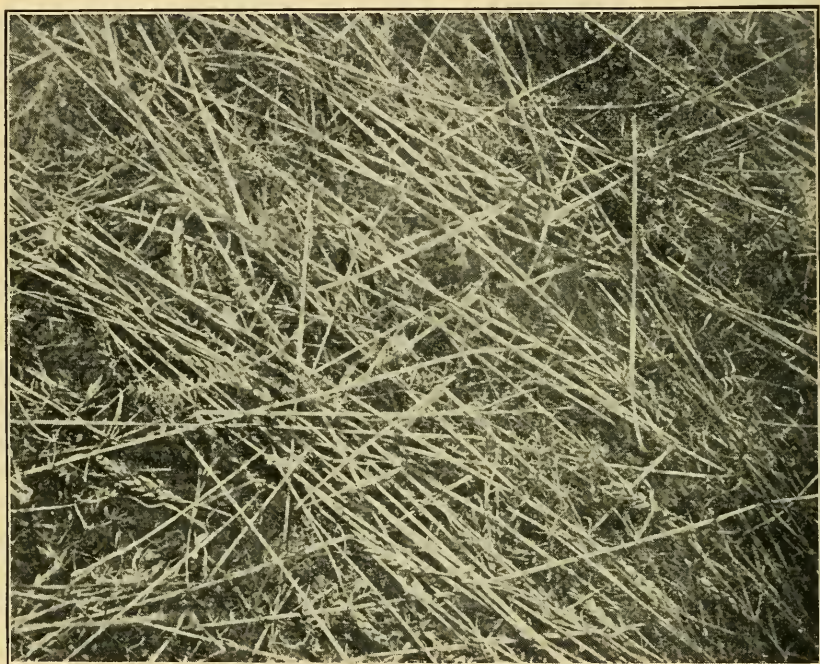


FIG. 5.—Bird's-eye view of wheat in Thomas Yeam's field, Souris, N. Dak. Ninety per cent of these fallen wheat stems have been mined by the western grass-stem sawfly.

The spring of 1917 witnessed a peculiar condition of things in Bottineau and the adjoining counties of North Dakota. The dry weather hindered the growth of both grasses and grains, so that when the adult *Cephus* began to appear in June there was almost no opportunity for oviposition. Stems of *Bromus* from chance sods growing among wheat and on waste ground were filled with eggs. Young plants of spring wheat that had barely begun to joint were attacked and often contained as many as three and four eggs placed in the stem close to the ground. With a few strokes of the net 136 adults were swept from young wheat, so numerous were the flies at that time. In spite of the unfavorable oviposition conditions of that spring, the

eggs appear to have hatched and at harvest time the majority of the wheat stems had been bored and many were cut off at the base. Careful harvesting and the use of horse rakes saved a large proportion of what otherwise would have been a total loss. The infestation was much more general than in 1916.

A somewhat hasty reconnaissance was made through north-central North Dakota in August, 1919, that it might be ascertained as definitely as possible just how the *Cephus* attack was progressing. A number of fields in Bottineau County were examined and found to be heavily infested. Most of these had been raked after harvest and it was consequently impossible to compute accurately the percentage of infestation. The numerous sawfly-inhabited stubs in the drill rows, however, proved the severity of the attack. It was roughly estimated that about 30 per cent of the grain had gone down in most of these fields as the result of *Cephus* work. This figure is probably very conservative.

It is conceded by many observers in that region that the injury during the year 1919 was greater than during any previous year since the study of this pest was begun. More fields had been seriously invaded and were injured to a larger extent than had before been observed. Even fields of durum wheat, hitherto believed to be nearly free from fly attack, were severely injured in 1919, if the statements of reliable farmers are to be accepted. The question of immunity of durum wheat will be discussed later in this paper.

It may be stated, however, that the farmers are profiting by past experience and have used horserakes in stubble fields to such an extent that the percentage of actual loss of grain has been reduced to a small figure. The quality of grain from the fallen straw is naturally somewhat below the normal, since the work of the larvæ in the stems produces some injury in the heads as they fill.

Cephus was found mining wheat near Hettinger in southwestern North Dakota, July 18, 1917. September 22, 1917, infested wheat was found near Mott, 30 miles north of Hettinger. In October of the same year many wheat fields in Towner and Cavalier Counties, in northeastern North Dakota, showed heavy infestation, although during the previous year it was difficult to discover more than a trace of *Cephus* presence in the wheat in this region. None was found in the vicinity of Fargo, although it doubtless occurs throughout the entire Red River valley.

A gathering of sods of *Elymus canadensis* sent to the writer from Charleston, Mo., during the summer of 1917 contained at least one larva of *Cephus cinctus* that had been boring the stem of this grass in that region. This locality is a little south of the latitude of Pinto, Utah, where this insect abounds.

Roughly speaking, so far as is now known, the sawfly inhabits an area bounded on the north by a line far into Canada; on the east by the Mississippi River, or probably a little east of that; on the south by latitude 36°; and by the Pacific Ocean on the west.

From the foregoing brief summary of its history it will be seen that *Cephus cinctus* is distributed over an immense territory and that it constitutes a potential menace to the small grains throughout this vast area. As the acreage of native grasses is decreased from year to year by the bringing of wild lands under the plow, pests such as the sawfly will be forced to depend in an increasingly large measure upon the small grains and other products of the farms. On this account the injury caused by these formerly harmless insects bids fair to increase steadily. In the past the numbers of grass-feeding insects such as the one considered in this paper have been governed mainly by the supply of food plants. A dry summer that retarded the growth of long-stemmed grasses would automatically reduce the numbers of the insects that lived within these grass stems and perhaps bring certain species to the point of extinction. It is easy to see how seasonal fluctuations in vegetation would, to a large extent, either multiply or diminish the numbers of these insects.

Then again, the farmer, by introducing fields of grain into a region previously uncultivated, brings in conditions unknown before and invites the attack of these and other formerly harmless insects, making it possible for them to become a menace to his future. Such a study of life history as has been attempted in this paper is urgently necessary in order that control measures may be undertaken successfully when such insects become pests.

FOOD PLANTS

The various species of *Agropyron* and *Elymus*, genera both of which are well represented in the West, appear to have been the original hosts of the larvæ. Since their feeding habits have been modified by changing agricultural conditions, the list of their present host plants, so far as known, stands as follows:

<i>Elymus canadensis</i>	<i>Agropyron occidentale</i>	<i>Calamagrostis</i> spp.
<i>Elymus condensatus</i>	<i>Agropyron caninum</i>	<i>Festuca</i> sp.
<i>Agropyron tenerum</i>	<i>Hordeum jubatum</i>	Wheat
<i>Agropyron richardsoni</i>	<i>Bromus inermis</i>	Durum
<i>Agropyron smithii</i>	<i>Phleum pratense</i>	Spelt
<i>Agropyron repens</i>	<i>Deschapsia</i> sp.	Rye

Barley probably should be added to this list.

Since the larva is wholly unable to move from one stem to another, it is very obvious that the host stem must be large enough to afford both shelter and food during its entire growing period. Hence only the larger-stemmed grasses can be mined successfully by the *Cephus*

larvæ. Occasionally an unusually vigorous plant of a slender-stemmed grass, like *Hordeum jubatum*, affords stalks with diameter sufficiently great to be attacked by *Cephus*.

Small grains, such as wheat and rye, readily serve as hosts to this insect, because they are of suitable size and the length of their growing season coincides with the growth of the larva. Even if harvest time should happen to come before the maturity of the larva, the reaping machine probably would sever the stem far enough above ground to leave the larva below the sickle cut, where it could house itself safely before the end of the season.

Judging the future by the recent past, it seems probable that this fly, before another decade is past, will be found attacking practically all of our native and cultivated grasses and most of our grains.

It must be remarked in this connection that up to the present time this species has confined itself entirely to the West and has been found in only a few localities east of the Mississippi River. Its choice of wheat for food has taken place, so far as known, only in North Dakota and western Canada, although it is probable that Montana wheat fields have been invaded. From present appearances its attacks probably will be confined to vegetation growing within the area where spring wheat is sown.

THE EGG

The egg of *Cephus cinctus* is, when newly laid, decidedly crescent-shaped, glassy in appearance, milky-white in color, usually quite symmetrical, the ends of the crescent tapering and rounded. It is marked by very faint, short, longitudinal lines or wrinkles, placed without regard to order or pattern.

The size of the egg varies with the size of the female that produced it and measures from 1 mm. to 1.25 mm. in length. The greatest breadth is about one-third the length.

The covering membrane is hyaline and transparent. Although very thin and delicate it is sufficiently strong so that the egg may be safely lifted and moved by the aid of a fine brush. The egg always lies free within the stem of the host plant, either in the stem cavity or in a hollow excavated by the ovipositor of the female that placed it. This cell is always a little larger than the egg, so that it is comparatively an easy matter to remove the egg to a moist cell or elsewhere for study.

The number of eggs distributed by each female appears to vary but little. Dissections of a number of adults taken in the field and of others reared in captivity agree in most cases in giving a count of about 50 eggs in the ovaries, these eggs being, as a rule, equal in size and apparent maturity.

DEVELOPMENT OF THE EGG

After a number of trials it was found to be impracticable to rear the egg *in situ*, since it was next to impossible to maintain the proper moisture conditions within the stem. The method that finally was adopted, and that gave excellent results, was to remove the egg from the stem and place it in a minute drop of water within a small thin watch glass which was then immediately inverted on a glass slip and sealed with a ring of water to prevent undue evaporation. This form of moist cell proved quite satisfactory and permitted continuous examination of the egg with a moderately high-power lens during the entire period of incubation. It was found necessary, in order to continue the requisite moisture supply during a period of several days, to invert over the sealed cell a larger watch glass and over this in turn a tumbler. In this manner evaporation was reduced to a minimum. It is altogether probable that the amount of moisture in such a protected cell exceeded that normally present within the grass stem, but in every egg treated in this way the incubation appeared to proceed naturally.

Temperature and moisture are, without any doubt, the prime factors that hasten or retard the egg development. The temperature maintained within the laboratory during the course of these investigations was much more equable than that in the field, where, as in Utah, the heat of the sun through the daytime, followed by a chilly night, must alternately hasten and check development. The data given below, therefore, may only approximate what actually takes place under field conditions.

A few hours after the egg leaves the oviduct the milky-white contents of the egg which at first completely filled the envelope shrink a little from each end leaving a transparent space or vacuole. Gradually the interior mass of exceedingly minute particles coalesces until about the second day when a series of faintly discernible cells arranging themselves along a central axis begins to appear. Early on the third day the form of the larva can be dimly seen, the head being almost transparent and filling one end of the egg sac. The body is looped on itself, the cauda folded beneath the abdomen and extending forward nearly to the head. By the close of the third day the abdominal segments are usually well defined.

During the fourth day, in most cases, a spasmodic and intermittent heart beat may be noticed. These pulsations become more and more regular as the hours pass and during the fifth and sixth days the heart beats with much regularity at the rate of about 120 impulses per minute. At intervals, for some unknown reason, it may slow down to 75 beats, but soon resumes its former rate.

The head appears abnormally large at this time, but although its general outlines are well defined the brown jaws and eye spots are

not yet visible. Over night, at the close of the fifth day, the jaws turn brown and the eye spots appear and darken. Usually, after the fourth day, the muscular system of the larva is in almost constant motion, shifting and adjusting, with the heart pulsating and the muscles moving, all clearly to be seen through the transparent membrane that serves as the shell.

The activity of the larva within the sac increases during the sixth day, and either on this day or the seventh it escapes from its confinement by a series of convulsive movements that rupture the delicate shell and set it free.

After the first day the egg changes shape, becomes intumescent, generally loses its crescentic shape entirely, and grows oval or reniform in outline.

THE LARVA

When it escapes from the egg the larva (fig. 6) possesses a very large head armed with a pair of powerful biting jaws, a weak, slender body, and a most vigorous appetite. It is very active from the start and begins almost at once to feed upon the living parenchymatous tissue by which it is surrounded in the interior of the stem, excavating for itself a threadlike gallery both above and below the spot where the egg formerly lay. The larva is at first nearly transparent and colorless until it becomes filled with the tissue on which it exists.

The body segments are strongly and clearly marked from the time the larva leaves the egg. The jaws are brown, three or four pointed, the points chisel-shaped, beveled on the inside edge. The brown face plate is filled with crossed bands of striated muscular fiber that actuate the powerful jaws which form the most important item of the domestic economy of the young *Cephus*. The caudal horn, by means of which the larva moves up and down in its gallery, is also brown and is armed, even in the first instar, with a series of stout bristles at the base of its cylindrical and squarely truncate extremity. The larva is footless, the position of the legs being marked by minute, rounded tubercles terminating in a few short bristles.

Although the primary excavation made by the larva may extend for a short distance above the egg cell, the general course of the progress is invariably downward. In its earlier stages of existence, at least, the larva traverses its gallery several times, swallowing repeatedly the same fragments of tissue that have already been devoured during the first excavation of the stem. Young larvæ are



FIG. 6.—Western grass-stem sawfly: Newly-hatched larva. Greatly enlarged.

frequently found several inches above the lower end of the boring, moving through the solidly packed "sawdust." As the larva approaches maturity it is doubtful if it ventures into the upper and slender part of the stem, but it still reworks the frass farther down, enlarging the bore in places.

The number of instars is difficult to determine, owing to the larval practice, just referred to, of passing all the frass several times through the digestive apparatus. Nearly all the cast skins disappear completely under this treatment, only the heavily chitinized parts such as the jaws and caudal horn being recognizable in the burrow. Care-



FIG. 7.—Western grass-stem sawfly: Mature larvæ removed from their galleries. Enlarged 4 diameters.

ful investigation of these fragmentary remains appears to establish the fact that there are four molts. The contents of innumerable stems have been examined with scrupulous care and with varying results. In a few cases as many as four sets of jaws and in others four caudal horns have been found, mixed with the frass within the stems. Seldom were more than four sets removed from a single stem; usually only three were found. As is stated elsewhere in this paper, it is no uncommon thing to discover two and even three larvæ mining a single stem, although but a single individual can possibly reach maturity with the amount of nutriment contained in

one stem. It is believed that the larva that finally reaches maturity has devoured its rivals. It is obvious that the remains of these superfluous individuals would naturally be counted when a census of exuviae was undertaken and would complicate the result. But from the best evidence obtainable it is almost certain that there are five instars in the larval life of this species.

The length of the larval period is probably about 60 days, varying more or less with the warmth of the summer and the state of maturity of the host stems. The acceleration or retardation of the oviposition period owing to an early or late spring has much to do with the date of maturity of the larvæ, and possibly with the length of the larval period. August 29, 1911, at Kimballs, Utah, at an elevation of 7,000 feet, the writer found mature larvæ in stems of *Elymus condensatus*. The next year, at the same place, oviposition was beginning freely during the first week of July. The determination of the larval period is wholly inferential, based upon the findings in a series of stems (figs. 7 and 8).

The full-grown larvæ vary greatly in size, their growth being governed, as is usual in the case of such borers, by the quality and quantity of food consumed. Those living in wheat stems are much smaller as a rule than those found in rank-growing grasses such as *Elymus*. Measurements of a series of individuals give variations of from 8 to 14 mm. in length and from 1 to 2 mm. in diameter.

When mature the larva always seeks the extreme base of the stem, where it soon begins its preparations for hibernation. Its first move is to cut a neat V-shaped groove entirely around and inside the stem, usually at or a little above ground level. This groove never severs the stem completely, but so weakens it that the upper stalk, swayed by the wind, will break off completely when dry, leaving a stub that is very characteristic of the work of this insect (fig. 5). In this simple manner the larva provides for the easy escape of the adult in the following summer. The length of the stub thus formed varies greatly. In *Elymus condensatus* the stub sometimes will project above the ground as much as 3 or 4 inches, while in other grasses, and especially in wheat, stubs easily can be found less than an inch in length in all.

Instances have been observed where two or more grooves had been cut inside the same stem, as if the larva had been uncertain as to the best place for severing the grass. After cutting its characteristic groove within the stem the larva forces a mass of the débris into the



FIG. 8.—Western grass-stem sawfly: Mature larva. Enlarged 5 diameters.

bore just below the groove and in this manner plugs the upper end of the stub that is to be left in the ground after the upper stalk has been broken away (figs. 9, 10, and 11). This dry frass in some manner is packed firmly into its place, perhaps by means of pressure rather than by being cemented with a liquid furnished by the larva, since the plug is readily penetrated by moisture. This is somewhat remarkable in view of the fact that an undue amount of moisture appears to have a disastrous effect upon the mature larva. One would suppose that these stubs, often wholly submerged in water-soaked earth for weeks at a time, would absorb, during the long period of hibernation, a fatal amount of dampness from the rain or melting snow. But there is no evidence that this ever happens.



FIG. 9.—Western grass-stem sawfly: Infested wheat stubs from Bottineau County, N. Dak.

September 16, 1911, one of the larvæ was removed from the hibernation chamber and placed in a small vial, still inclosed within the silken tube or cocoon, which was unbroken. For months this larva remained passive and motionless except when the vial was exposed to bright sunshine. Because of the light or heat, or both, when placed in the sunlight it would become active at once, and travel up and down within its cocoon in its efforts to escape. January 20, 1912, to prevent the air in the vial from becoming too dry a small drop of water was introduced and the vial again corked tightly. An hour later it was noticed that the silk tube had collapsed and the larva within was limp and apparently dying. The surplus moisture was removed quickly, whereupon the larva revived almost at once.

If the same amount of moisture had entered the stem where the larva was hibernating it probably would have caused its death. This experiment, taken in connection with others that were not so directly conclusive, seems to prove that the porous plug in the stub must prevent in some way the admission of an undue amount of moisture into the chamber below, although water readily penetrates it.

The gallery below the plug is always entirely free from débris, forming a hibernation chamber and later a pupation cell. Within this chamber the larva lies with its head up and usually pressed against the barrier at the top, always on the alert to retreat downward at any sign of disturbance. It descends by alternately flexing and straightening the body, bracing itself first by the jaws, then by the caudal horn as it hitches its way down. In ascending, the caudal horn is thrust against the side of the gallery or the cocoon, the body is straightened, the jaws obtain a purchase to hold the distance gained, when the body is again drawn up until the caudal horn is applied to the side wall for another push.

Late in the summer or during the autumn the larva spins for itself within the hibernation chamber an almost transparent tube of filmy silken

tissue. This silk tube is sometimes several times the length of the larva, is closed at both ends, and is free from the sides of the chamber, so that often it can be readily withdrawn entire. When first constructed this fabric is comparatively strong and pliant but after some months it grows more brittle and is easily ruptured. As a rule it remains intact until the emergence of the adult. Even the presence of half a score of parasitic larvæ often fails to wreck the delicate structure during the winter.

The longevity of the sawfly larvæ is remarkable and is worthy of mention. September 8, 1911, a number of stubs of *Elymus condensatus* containing *Cephus* larvæ were gathered and set upright in sand within doors. From time to time this sand was moistened but finally was allowed to stand perfectly dry. During October, 1912,

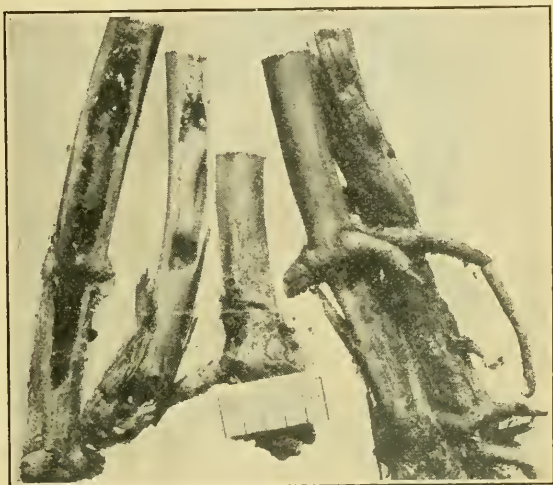


FIG. 10.—Western grass-stem sawfly: Infested wheat stubs, enlarged 3 diameters, the two left-hand ones opened to show hibernating larvæ *in situ*.

these stubs were examined and a number of the inclosed larvæ were found to be still living, active, and unchanged. Four months later, 17 months from the time they were gathered, they were still alive and feebly active. Infested stubs of the same grass taken during September, 1912, and treated in the same manner, contained at least one living larva on February 23, 1916, 3 years and 5 months later. The others had nearly all died within about 30 months of the time they were gathered. It is possible that the lack of necessary moisture may account for the retardation of these captives. However, the same retardation of development has been noted in the field. Inhab-

ited stubs of the previous year's growth of grass and grain not infrequently have been found, containing larvæ that were to all appearances entirely normal and active. It appears more than probable that in this manner the perpetuation of the species is assured in case of unfavorable seasons.

During the winter the larvæ are, of course, frozen, or are chilled into immobility and show no signs of life when disturbed. As soon as the earth warms in the spring they again grow active and move freely up and down within the limits of the silk-lined hibernation chamber until the time of pupation arrives.

THE PUPA

The pupa when first formed is milk-white, slender, and somewhat longer than the larva from which it was derived. Its average length

is not far from 12 mm. and its breadth is about 1.5 mm. At first the pupa lies motionless within the silken pupation chamber or cocoon (fig. 12) for probably a day or two, after which inactivity it again becomes animated. When disturbed it will endeavor to escape the threatened danger by moving either up or down the tube, hitching itself along in much the same manner as the larva but going a lesser distance with each effort. Like the larva it is almost always found with its head pressed closely against the plug of frass at the upper end of the chamber. In a few cases pupæ have been discovered heading downward in the stem. It is doubtful if these can reverse

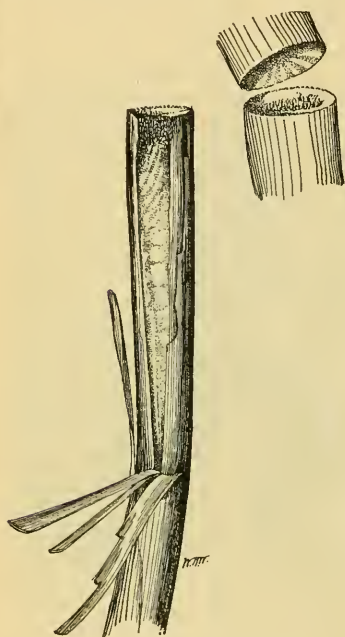


FIG. 11.—Stems of wheat grooved internally by larvæ of the western grass-stem saw-fly.

their position, but the adults which issue are probably agile enough to turn about and escape.

The duration of the pupal period is not known certainly, but is believed to be very brief, not more than a week at the most. After the first day the legs and body darken until they become a lustrous black within the transparent, almost invisible filmy membrane in which they are inclosed. This membrane is often lacking and may occasionally be destroyed by the movements of the pupa within the chamber.

When fully mature the pupa changes within the cell to an active adult. This adult remains imprisoned until some unknown impulse compels it to force its way upward through the plug of frass placed at the upper end of the chamber by the larva 9 months before. The writer, by splitting stubs of grass or grain in June, has liberated adults repeatedly, which, when free, were able to take instantly to wing without any preliminary process of drying or other preparation. These adults were evidently resting, in perfect condition, waiting for some secret signal from the outside world before taking the final step for liberation.

A very few die within the cell, possibly because of lack of vitality needed to break through the stopper of frass above them. In cases where the girdling of the stem was inefficiently done, so that the grass stalk did not break off during the winter season, the adult dies as a matter of course, since these flies apparently are not fitted with jaws capable of biting through the woody stems of dry grass.



FIG. 12.—Western grass-stem sawfly: Pupa. Three and one-half times natural size.

THE ADULT

The adult *Cephus cinctus* is a beautiful insect with a polished black body marked by three prominent yellow bands across the abdomen. The legs are yellow and the wings smoke-colored.

The description, by S. A. Rohwer, follows:

Length 7 to 12 mm. Head shining, polished; anterior margin of clypeus truncate with angles prominent and sometimes slightly denticulate; antennæ usual for the genus; thorax shining but with setigerous punctures on scutum; sheath nearly parallel-sided but a little broader at base, apex truncate with corners rounded; hypopygidium rather narrowly subtruncate apically. Black marked with bright lemon yellow, amount and extent of yellow markings varying greatly; head of female usually black but more rarely with face entirely yellow or having yellow spots; head of male black but always with yellow on face; thorax black, the upper angle of mesepisternum, parapteron, and scutellum (usually) yellow; legs yellow with coxæ, trochanters (occasionally both of these having yellow marks), bases of femora more or less, apices of tibiæ and tarsi sometimes, black; hind tibiæ and tarsi sometimes reddish yellow; abdomen black, spot or band on second tergite, band on third, fifth, sixth, and eighth

tergites and lateral margins of tergites yellow, the size and extent of these markings varying and occasionally the fourth tergite having a yellow band; wings fuliginous, venation dark brown, costa and stigma yellow.

The female is noticeably larger than the male, and in the field is captured much more easily.

The characteristic attitude of the adults of either sex while at rest is to lie flat against the grass stem, head downward, the body closely appressed to the stem, the legs not spread but stretched in line with the body while the body itself is concealed behind the closely folded, smoke-colored wings. The ease with which such a strikingly colored fly, while in this position, can escape observation, is remarkable. During the chill of the morning and after sundown this attitude is universally assumed. When basking in the sun at midday, on the warm side of a grass stem, the fly is much less compact, with the wings partly spread and the legs outstretched in order to absorb the utmost of the warmth. Like most Hymenoptera, this species is very partial to sunshine and rarely is seen abroad on a cloudy day. In fact, in cloudy weather it is not easy to find these flies at all, unless one is entirely familiar with their habits.

They are weak fliers and seldom travel to any great distance at one time. In Utah they commonly move about among the plants of bunch grass, making short flights from tuft to tuft. If the wind rises or the sun goes behind a cloud they promptly disappear until conditions again become satisfactory. The writer has never taken the adults at any great distance from their breeding places.

Their hovering flight is peculiar, the swaying motion of their bodies in the air reminding one of certain tipulid flies during their mating air dance. They often hover for a long time to the windward of a grass plant without alighting, seeming to enjoy the motion. The males are on the wing much more than the females, but neither sex will remain in the air while the wind is strong or when it is cool. The adults are not at all timid and can often be readily taken from the grass stems with the fingers. When conditions are favorable for her the female is usually too intent on oviposition to be easily annoyed but if disturbed beyond endurance she quickly disappears, her dark color and slender body enabling her to vanish completely among the vegetation.

Copulation is very brief, usually lasting less than a minute. No notes were made on the attitude assumed during the operation.

The species is single brooded, the adults appearing during the spring and going out of existence some time about midsummer.

The earliest individual met in Utah was taken in a net April 26, 1910, in an alfalfa field. Adults have been seen in the mountains late in July and they probably linger longer than that, ovipositing in such green grass stems as they can find. Near Kimballs, in Utah, September 8, 1911, the writer took very young larvæ from stems of

Elymus condensatus, growing from plants that had been browsed by cattle and had thrown up fresh green stalks.

Mr. Norman Criddle states that in Canada the adults appear during the second week in June and may be met with until about July 10. Occasionally they may be found feeding on flowers. Doctor Fletcher has taken them in Canada on flowers of the tumbling mustard. It is unquestionably true that the time of their appearance and the length of adult life are both largely governed by climatic influences and vary with the season.

When confined in emergence tubes or other limited places the males develop savage instincts and attack each other without mercy, using their jaws freely to snip off the antennæ, and, in some cases, the legs of their rivals. Singularly, very few of the females confined with them are thus mutilated.

OVIPOSITION

Weather conditions have always been an important factor in controlling the oviposition of very many of the Hymenoptera, and they are of particular importance in the case of the *Cephus*. These flies go into hiding when the day is dark, damp, cool, or windy. Only on bright, warm, still days are they to be found busy with the operation of placing their eggs. In Utah, where the first studies of their habits were made, the mornings and evenings are chilly as a rule, hence the activity of these flies is confined to the hours near midday. They are everywhere the most active between the hours of 10 a. m. and 2 p. m.

The swaying of the grass and grain stems in the wind appears to be a hindrance to them in alighting and ovipositing. A gentle breeze will often keep them hovering for several minutes to the windward of their goal, while a sudden mountain gust is apt to put an abrupt end to all efforts for the balance of the day. Their actions are controlled by unknown factors, for sometimes on a still, sunny day they will spend much of the time roosting on the stems, while again, under apparently the same conditions, they are constantly in motion, flying and hovering a long time before alighting.

While the female is poised in the air before a sod of grass or grain she is evidently busy selecting the particular stem in which she hopes to oviposit. Once she has chosen and settled, she seldom changes to another stalk, although she may halt at several places on a single stem and attempt oviposition at each pause. Occasionally, after a hasty examination, she may again take to wing and make another choice. Repeated observations seem to have established the fact that one of the chief requisites of a proper stem is that it shall not yet have put forth a head. In all the countless instances where oviposition has been observed, the female has never been known to choose a stem with a head.

When she has made her selection of a suitable stem, the female usually alights about half way up and runs briskly to the upper end, halting almost imperceptibly every few steps. The gait of an ascending fly is so characteristic that it determines with much certainty if the individual is a female intent on oviposition.



FIG. 13.—Western grass-stem sawfly: Female ovipositing. About life size.

Arriving at the apex of the stem, after a careful survey of its condition, she frequently makes an elaborate toilet, preening herself most carefully, until she is in perfect condition. She then descends, exaggerating slightly the hesitating step by which she had ascended. The antennae are held horizontally in front of the head as she moves, and she occasionally touches the surface of the stem with their tips. There is none of the rapid antennal vibration so common among the smaller chalcids and many other Hymenoptera. She gives no evidence of being in search of any particular point, but goes straight down the stem.

When satisfied that she has gone far enough she halts abruptly, usually an inch or less above the second node from the top of the stem, slowly arches her abdomen and clasping her hind pair of feet around the stem as far as they will reach begins to drive the saws into the hard outer tissue. Figure 13 shows the attitude taken at this time. These saws are exquisitely fashioned, curved like a scimitar, double, very thin with serrated edges. (See fig. 14.) They are used to split the outer coating of the stem rather than to cut it, and they make an opening so exceedingly small that it is almost impossible to find the scar after the wound has healed. These saws are gradually forced into the stem, the operation occupying a minute or more. In the field the female always heads downward during oviposition and the curve of the saw blades brings them, when fully inserted, in a line parallel to the axis of the stem. They are frequently partly withdrawn and their direction slightly changed. When the stem is in proper condition the saws are thrust in several times, as far as they will go, then are withdrawn,



FIG. 14.—Western grass-stem sawfly: Saws, greatly enlarged.

the dorsal part of the pygidium being used as a fulcrum to extract them. They are inserted again, this time often with a twisting motion as if trying to enlarge the opening. They are finally forced in as far as possible, as is evidenced by the tenseness of the rear legs straining at the stem, and are held in this position for half a minute or more. This is probably when the egg is deposited, the insect standing practically motionless except for a slight vibration of the antennæ.

A laboratory note may be of interest, giving in detail some of the facts that have been mentioned above:

June 5, 1912. The adult *Cephus* were emerging freely from the *Elymus* material brought from the mountains, and it occurred to me it might be possible to secure some views with the camera if they could be induced to oviposit. Several females were observed attempting oviposition in the dry stems from which they had recently emerged.

A green stem of *Elymus* was planted in a tumbler of wet sand and the camera focussed on this stem about midway. After a few trials I discovered that this stem must be short and headless.

The females were taken from the cage and placed, one at a time, on the damp sand in the tumbler. Their first act in every case was to spend a long while drinking eagerly of the water held in suspension by the sand. A few of them sipped water for as much as half an hour before they could be induced to leave. When guided to the base of the *Elymus* stem they would usually ascend without a moment's hesitation. Once started they would go to the very top and there would either preen themselves interminably, or would wheel and descend with the usual cautious, hesitating gait, a few steps at a time. When part way down, without apparently choosing any especially suitable spot, the abdomen would arch and oviposition would begin. Sometimes these efforts were plainly failures, but some of the flies would sink their saws well into the tissue of the stem and stand for a number of seconds motionless, thus affording an opportunity for the camera.

Much time was lost to-day because of the exasperating neatness of these insects. Each one would brush herself over and over again with the most minute exactness and no amount of urging would avail to shorten the process. The same careful preening has been frequently observed also in the field.

Several life-size views of these flies were obtained to-day by the above method, views that would be impossible in the field because of the almost constant motion of the limber grass stems. Several of the females became confused to-day when compelled to remain on a certain part of the grass stem during oviposition, and faced up the stem instead of down as they invariably do, normally.

When busy with oviposition they seem oblivious to whatever is going on around them, and the writer has repeatedly watched, through a half-inch triplet, the female manipulating her saws. Close observation did not annoy her in the least when the lens was carefully handled, and she paid no attention to the proximity of the onlooker. Under the closest scrutiny it is impossible to determine just when the egg is passed into the stem. It is probably at the time when the female stands motionless after the saws have been driven in to their full length.

The function of these saws appears to be twofold. At Pinto, Utah, in June, 1912, the writer found that the eggs were invariably placed

in a cell hollowed in the solid parenchyma of the stem of *Elymus condensatus*, this cell being a little larger than the egg. Besides piercing the stem, the saws are also of use in excavating this egg cell, in case such a cell is needed. At Kimballs near Salt Lake City, in the same grass, the eggs were nearly always placed in the hollow part of the stem, lying free in the central cavity.

Normally but one egg is placed in each stem. However, no attention is paid to previous oviposition and as many as five eggs have been taken from a single stem. As is stated elsewhere, only one of these larvæ can possibly survive until fall, so this multiplication of eggs simply means economic waste for the *Cephus*.

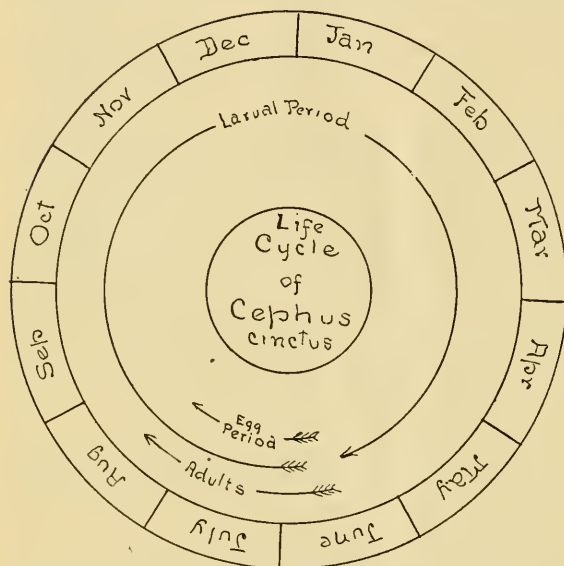


FIG. 15.—Life-history diagram of the western grass-stem sawfly.

ited during June. The date of oviposition in the Dakotas and in Minnesota is unknown. (Fig. 15.)

KEY TO THE NORTH AMERICAN SPECIES OF CEPHUS

Through the courtesy of Mr. S. A. Rohwer of the Bureau of Entomology a key for the determination of the known species of the genus *Cephus* occurring in North America is here presented.

- Stigma and costa dark brown of a uniform color; mesepisternum black; femora black; apical tergite and venter black; face and scutellum black (face of male with yellow spots).....*pygmaeus* Linnaeus.
- Stigma in greater part and costa yellow; mesepisternum with the upper angle yellow; apical tergite and usually the venter in part yellow; femora usually mostly yellow; face and scutellum of female usually black but occasionally with yellow spots.....*cinctus* Norton.

The date of oviposition varies with the latitude and the altitude. At Pinto, Utah, on the edge of the desert country and with a low altitude, newly hatched larvæ were found June 14, 1912, while at Kimballs, 350 miles north of Pinto and with an altitude of 7,000 feet, oviposition was beginning during the first week of July in the same year.

Mr. Criddle states that in Canada most of the eggs are depos-

NATURAL CONTROL

In the usual scheme of things an undue increase of insect pests is controlled naturally by parasites that take a heavy toll of their hosts and prevent their multiplication. Under normal conditions, when the *Cephus cinctus* existed wholly in grass stems, the larvæ were attacked with varying success by two or more species of parasites that destroyed numbers of them and kept them within reasonable bounds. Since the fly has begun to change its habits and to subsist on wheat and other small grains to a certain extent, these parasites apparently have not yet learned of the change and are confining their attacks, as heretofore, almost entirely to those larvæ that they find in grass stems. A very few parasites have been taken from infested wheat stubble, and there is little question but that in course of time the busy little parasites will hunt their prey in the grain stems and do their share in helping to control this pest.

The most common parasite found everywhere in the grasses is *Pleurotropis utahensis* Cwfd., a beautiful little bronze-green chalcid that was reared by the writer from numerous larvæ taken near Salt Lake City, Utah, from *Cephus* hibernation cells. This species appears to kill the larva only after it has formed its hibernation cell. It is gregarious and seldom or never attacks its host singly. As many as 12 of its larvæ have been taken from a single cell, but 5 or 6 is a more common number. These larvæ are white and measure from 2.5 mm. to 3.5 mm. in length. They are somewhat active and travel slowly about the cell when mature. They are often found crowded together in one end of the cell, but when disturbed will scatter about the chamber (fig. 16).

Although this species is widely distributed and propagates in numbers it appears to destroy but a small percentage, possibly 10 per cent of the *Cephus* larvæ in the native grasses of Utah. In Bottineau County, N. Dak., it attacks the sawfly very freely in *Bromus* and timothy, and in some localities has killed more than 50 per cent of the *Cephus* larvæ. Indeed, it and one other parasitic

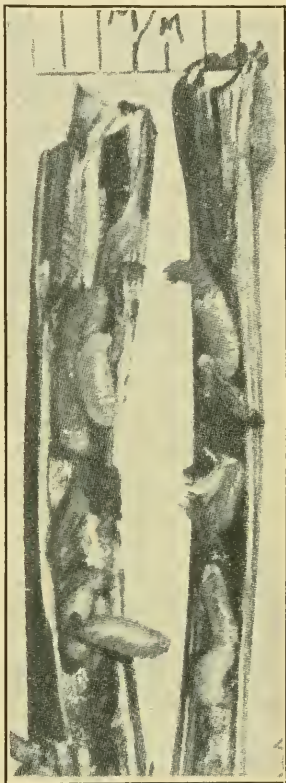


FIG. 16.—Larvæ of *Pleurotropis utahensis*, a parasite of the western grass-stem sawfly, *in situ*.

species are so numerous in these roadside grasses that it would seem poor policy to recommend the cutting of the grasses in midsummer as a measure of *Cephus* control. As has been stated, few parasites have been found in stems of wheat, but, without doubt, they will learn very soon of the presence of *Cephus* in grain fields and will adjust their habits accordingly.

A braconid, *Microbracon cephi*, recently described by Mr. A. B. Gahan,¹ also attacks the larvæ in grass stems, kills them before maturity, and spins a gray parchment-like cocoon within the gallery, generally near its lower end. This cocoon is truncate at both ends, its disklike extremities completely filling the bore. The adult escapes by biting an opening through the stem in the vicinity of the cocoon.

ARTIFICIAL CONTROL

From the foregoing sketch of the life history of the western grass-stem sawfly it seems obvious that this pest will have to be attacked while it is in the larval state. The egg and adult stages are both brief and are clearly beyond the reach of control measures of any sort. For nearly 11 months the insect exists as a helpless larva, protected only by the grass or grain stem within which it lives. If this stem could be destroyed, the larva within would perish.

The first remedy that occurs to the farmer or the student of field conditions is the burning of the stubble in the autumn or spring. It would seem a very simple matter to set fire to the stubble and destroy at least the majority of the sawfly larvæ that are hibernating in it. But when one begins to examine the infested fields it is found that the inhabited stems have been cut at the ground level or below so that it is often necessary to brush away the earth in order to find the stubs containing the larvæ. So little heat is generated when stubble is burned that these subterranean stems could not possibly be harmed by the quick passage of the flames.

In 1907 Mr. Norman Criddle, in Manitoba, wishing to make a thorough test of this particular remedy, spread a layer of straw several inches deep over an infested area in a wheat field and set the straw on fire. More heat was produced than stubble alone could possibly make, the surface of the ground being too warm for the hand after the fire had died down. Even after this severe treatment it was found that, as far as could be learned by a minute search, not a single larva had suffered. They had simply retreated to the lower end of the hibernation cell and "kept cool."

Another fact must be noted in this connection. When a field has been damaged seriously by the sawfly, the stubble remaining to feed a running fire is of necessity more scanty than in an uninjured field

¹ Gahan, A. B. Description of a new hymenopterous parasite (Braconidæ). In *Proc. Ent. Soc. Wash.*, v. 20, no. 1, p. 18-19. Jan., 1918.

and consequently it would be exceedingly difficult to burn such a field even under the most favorable conditions.

In Utah the bunch grass, *Elymus condensatus*, is much infested by this same fly and frequently is burned by fires that sweep the mountain side. This *Elymus* forms dense sods, with stems often more than 3 feet in length, and the heat from its combustion is great. The writer has examined a large series of burned sods and has seldom discovered any injury to the larvæ from the fire.

These facts would indicate the futility of burning the stubble as a control measure.

Although it might seem possible to decrease the numbers of the fly by mowing roadside and fence-row grasses during July, thus destroying the larvæ always present in the stems of these grasses, careful study has proved that a large percentage of the larvæ in these grasses is parasitized and therefore it would seem unwise to take steps that might diminish the number of parasites. Without any doubt grain fields in North Dakota and Canada are invaded regularly by sawflies that issue from grass growing along their borders. Still, because of the multiplication of useful parasites from this same grass it is probably inadvisable to mow the grass in midsummer.

Deep plowing, 5 to 6 inches, is perhaps the best remedy for the sawfly that can be suggested at present. It is much easier to advise this than to put it in practice. In almost every plowed field in any part of the country each furrow is marked by a row of stubble projecting from the inner edge of the furrow slice. Unless the stubble is turned squarely upside down, burying it at least 5 inches, the resulting surface at the same time being compacted by harrowing or rolling, the flies will be able to escape with ease from beneath the ground.

In the fall of 1916 the writer buried four lots of infested stubble in different depths of earth sifted and compacted by jarring. These were buried, one at 3 inches, one at 4, and 2 at 6 inches, in glass jars, 10 stubs in each of the first two, 20 in the other two. August 6, 1917, these cages were examined with results as follows:

Under 3 inches of earth all adults emerged.

Under 4 inches 1 larva died, all others emerged.

Under 6 inches 1 adult died in the cell, 6 larvæ also died, 2 active living larvæ still in the cell, all other adults emerged.

Under 6 inches 7 larvæ died in the cell, all other adults emerged.

Lumpy soil in the field might make it easier or harder for adults to emerge than fine soil in a jar, and this point might be difficult to determine.

Cultural conditions in North Dakota are not favorable for burying the stubble by plowing. Spring wheat is followed in many cases by winter rye which is disked into the wheat stubble after harvest. This

procedure leaves all the infested stems of wheat on the surface, and nothing could be more favorable for the escape of the adult flies in the following spring. The wheat stubble seems to be necessary to hold the winter snow for the protection of the young rye, hence the farmers seldom or never plow the stubble under before sowing the rye.

Previous to the year 1919 it had been stated with much confidence by men who were known to be good observers that durum wheat was nearly immune from the attacks of the sawfly. On the strength of these statements county agents were inclined to recommend a modification of ordinary farm practice, at least to the extent of barring from that region Fife and Marquis and the softer-stemmed wheats in the hope that by this means the work of the sawfly might be checked and a more certain harvest assured. It was readily seen that an immune wheat would solve the problem of the sawfly.

Observations made by the writer during the month of August, 1919, and recorded on an earlier page of this paper, included in their scope an inquiry into this question concerning the immunity of durum wheat. Farm work was too far along at the date of this visit to permit of effective field work to settle the matter definitely, but several farmers informed the writer that durum had suffered severely that year, although not as much as either Fife or Marquis. These reports must be accepted at their face value since the agreement on this point was general.

The immunity of durum may vary from year to year and is possibly based on the relative dates of the appearance of the adult *Cephus* and the rapidity of growth of the young grain. The stem of the durum wheat is more dense and unyielding than that of other wheats, and if a warm rainy spring should hasten its growth it might prevent the sawfly from placing many eggs. A number of unknown factors enter into this problem that hinder its complete solution at the present time.

CEPHUS PYGMAEUS L.

In certain parts of the country the occurrence of *Cephus cinctus* appears to have been confused with that of its congener *Cephus pygmaeus*, a sawfly stem-borer that was probably imported from Europe only a few years previous to the first mention of *Cephus cinctus* in the United States. The habits of the two species are so similar that a brief synopsis of the life history of *Cephus pygmaeus* is given herewith together with a condensed description of the same insect.

As far as is now known the imported species does not yet occur west of the Mississippi River, while the western grass-stem sawfly has been found for the most part only west of the same river.

C. pygmaeus was first observed in 1887 in the vicinity of Ithaca, N. Y., and in 1889 Prof. J. H. Comstock published ¹ an account of its

life history as worked out by himself. From this bulletin the following summary of its habits and appearance has been compiled.

The adults, in the latitude of Ithaca, appear during the month of May and at once begin oviposition in the stems of wheat, just as the grain is jointing. In the majority of instances the eggs are placed above the third joint, and the larval gallery extends from the point of oviposition, or a little above, to the extreme base of the plant. By the time the wheat is ready to cut, early in July, a large majority of the larvæ have descended to a position below the level of the reaper cut and are safe from removal with the harvested straw. A week later nearly all the larvæ have girdled the stems within and part have already spun the silken lining of the hibernation chamber.

Cephus pygmaeus is a well-known species in Europe and has been described by both English and Continental writers. In France it has been considered a very serious pest and is said to attack both wheat and rye.

DESCRIPTION

Adult shining black, banded and spotted with yellow. Length of male 8 mm., of female 10 mm. Head large with prominent eyes; three ocelli near summit. Antennæ inserted on front nearly opposite middle of compound eyes, and composed of 19 or 20 segments. Wings transparent, iridescent, somewhat smoky, with costal margin yellow toward base. Mouth-parts (except tips of mandibles), a spot on clypeus, a narrow margin between compound eyes and mouth-parts, ventral aspect of thorax, legs (except a dark band on coxæ and femora), membrane at base of abdomen, caudal margin of each abdominal segment ventrally, a more or less well-marked spot on each side of first and second abdominal segments, a broad band occupying caudal three-fourths of third and fifth segments, a narrow band on caudal margin of sixth segment often more or less interrupted forming spots on back and sides, and latero-caudal angles of seventh segment, yellow in male.

In female, spots and bands usually smaller and sometimes entirely wanting ventrally.

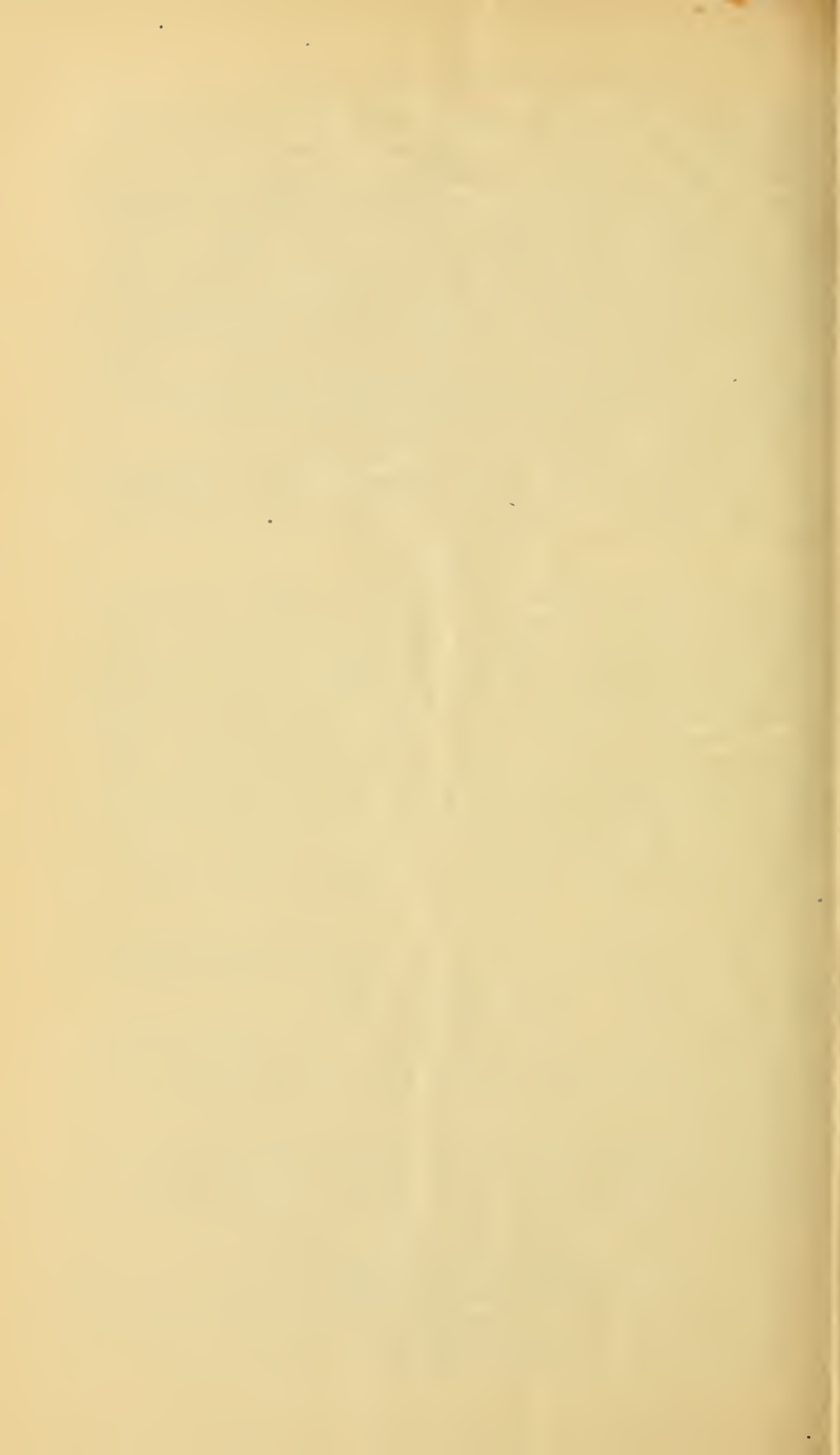
Both this species and *Cephus cinctus* vary greatly in their markings. Mr. S. A. Rohwer, of the Bureau of Entomology, who has given much critical study to this genus and has examined a large series of individuals, mostly reared from known host plants, states in a recent publication:² "The introduced, European, *Cephus pygmaeus* (Linnaeus) is very similar to the native species common throughout the west and it is difficult to find characters which distinguish the two in all their forms."

¹ Comstock, J. H. A saw-fly borer in wheat. In Bul. 11, Agr. Exp. Sta. Cornell Univ., Nov., 1889.

² Rohwer, S. A. The American species of the genus *Cephus* Latreille. In Proc. Ent. Soc. Wash., v. 19, p. 139-141. 1917.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 843

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief



Washington, D. C.

PROFESSIONAL PAPER

June 7, 1920

THE BEAN LADYBIRD.

By F. H. CHITTENDEN, *Entomologist in Charge*, and H. O. MARSH, *Entomological Assistant, Truck-Crop Insect Investigations.*

With a report on "The Bean Ladybird in Colorado, in 1919."

By A. C. MALLORY, *Scientific Assistant.*

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INTRODUCTION.

In the semiarid region of the Southwest, where an immense acreage of beans is grown annually, a destructive insect known as the bean ladybird, bean beetle, "bean bug," and spotted bean beetle¹ does great injury. Indeed, it is to the bean crop what the Colorado potato beetle is to the potato, a pest of the highest importance in the region which it inhabits.

The beetle devours all parts of the bean plant—leaves, flowers, and growing pods. Its main food supply, however, is the leaves, through which it cuts irregular holes (Pl. I; III; IV, fig. 1). Its injuries,

¹ *Epilachna corrupta* Muls.; order Coleoptera, family Coccinellidae.

NOTE.—This insect was under the observation of the junior author (who died September 10, 1918), from 1914 to 1917. The life-history investigations were conducted in an open-air insectary at Rocky Ford, Colo.; and some field operations were conducted also at Pueblo, Fort Collins, and Colorado Springs, Colo., and at Maxwell and French, N. Mex.

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so far as is known, are practically confined to beans, and no variety seems to be exempt from injurious attack. This insect has been observed feeding on various forms of the kidney bean (*Phaseolus vulgaris* et al.), including string, pole, navy, and tepary or Mexican, and on the lima bean (*Ph. lunatus*). Of these string beans are favorites. On one occasion the soy bean (*Soja hispida*) was attacked. The beetles, unlike those of the bean leaf-beetle (*Cerotoma trifurcata* Forst.), show no tendency to injure very young plants and the larvæ work on the lower surface of the leaves, skeletonizing large, irregular areas without cutting the epidermis or upper skin. (Pl. II, III.)

It is fortunate that its field of operations is limited, both as regards the crop plants affected and the territory over which it ranges. It has been estimated that it does an annual damage in New Mexico varying from 5 to 100 per cent of the crop, the average loss being conservatively placed at 10 per cent.

This species is remarkable in that it is one of two species of ladybirds occurring in the United States¹ which feed exclusively on vegetation, the other forms of the ladybird family being predacious and subsisting largely on plant-lice, or aphids, and the eggs of insects.

SYNONYMY.

The bean ladybird was described by Mulsant in 1850 (1, p. 815)² under the name by which it is known in economic literature, *Epilachna corrupta*. In the original description in which this name appears, printed under No. 90, *E. varivestis* is also described as No. 91, yet Crotch (3, p. 62), followed by Gorham (8, p. 242), recognized the latter as the proper name for the species, and relegated *corrupta* to synonymy, in which case the strict law of priority has not been followed. This species has evidently been described under at least a half dozen names, but as there is no means of deciding positively the exact term to apply to the species under consideration, *Epilachna corrupta* is here used to avoid further confusion, although *E. varipes* Muls. was described first and is acknowledged by Crotch and Gorham to be the same species. The name used by Bland (2), *E. maculiventris*, described in 1864 from the Rocky Mountain region of Colorado, undoubtedly applies to this species and naturally falls into synonymy.

DESCRIPTION.

THE ADULT.

The adult (fig. 1, *b*) is a robust beetle, oval in outline, and about one-fourth of an inch in length by about one-fifth of an inch in

¹ The other is known as the squash ladybird (*Epilachna borealis* Fab.).

² Reference is made by figures in parentheses to "Literature cited," p. 20.

width. The color of the newly developed adult is yellow, gradually darkening with age to a grayish brown. Each elytron or wing-cover is marked with eight small black spots of variable size.

Technical descriptions of the genus and species follow:

GENUS EPILACHNA.

Large, pubescent species related to *Chilocorus*. Sides of prothorax only slightly curved and broadly explanate; those of elytra rather strongly reflexed; epipleuræ horizontal, broadly concave, not distinctly extended to sutural apex. Metasternal and ventral lines well-defined, legs moderately retractile; femora not deeply sulcate beneath, tibiæ with an acute external edge, and shallow groove for reception of tarsi; claws cleft, with lower cusp nearly as long as upper.

EPILACHNA CORRUPTA MULS.

Form oblong, more narrowly oval than *borealis* and distinctly smaller, dull in luster, densely pubescent, and very closely, unequally punctate; color grayish brown; head and pronotum without spots. Each elytron ornamented with

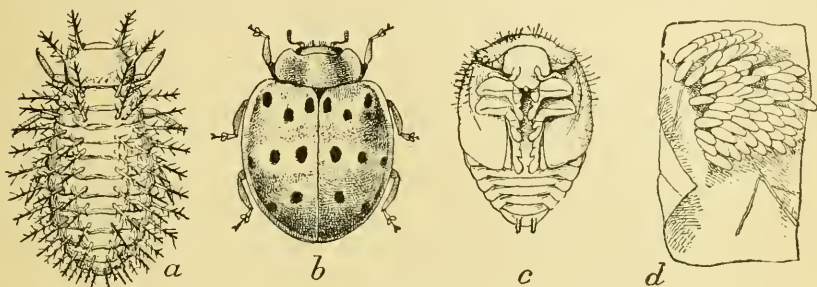


FIG. 1.—The bean ladybird (*Epilachna corrupta*): a, Larva; b, beetle; c, pupa; d, egg mass. About three times natural size.

eight spots or dots of varying size in three rows; three small sub-basal spots in a broken row, median less basal; three in a transverse subparallel row just before the middle, usually larger than sub-basal, median usually a little larger, and two near apical fourth, placed near inner fourth and outer third. Lower surface darker or concolorous with legs, which are pale throughout.

Length 6.5–7.8 mm.; width 4.8–5.4 mm.

The so-considered Mexican variety, *E. varipes* Muls., differs mainly from the species under discussion as it occurs north of Mexico in having the two subapical spots united or coalescing, forming an arcuate fascia. All spots are also larger and surrounded by a lighter aureole. The typical *varivestis*, as figured by Gorham, shows these aureoles, but they are less pronounced in many specimens from the United States.

Specimens occasionally occur of a more or less pronounced buff color, but these usually are not fully colored, being more or less immature when killed for mounting.

THE EGG.

The egg is dull pale yellow, elliptical in outline, approximately twice as long as wide, a little larger at the base or attached end than

at the apex. The surface is strongly sculptured. The length of the egg is 1.25 mm.; the width 0.6 mm.

The eggs are deposited on end on the lower surface of the bean leaves (Pl. IV, fig. 1) in irregular masses, varying from half a dozen to about 75, with an average of between 40 and 50. (See fig. 1, *d*.)

THE LARVA.

The larva is yellow and the body is armed with long, formidable, strongly branched spines, darker at the tips. When full grown these spines, although somewhat irregular, are arranged in rows both longitudinally and transversely, as shown in the accompanying illustration (fig. 1, *a*). The head is moderately prominent, as are the mandibles and other mouth-parts, which with the eyes are darker than the other parts. The legs are rather long and stout and the anal segment is obtusely and roundedly produced. The newly hatched larva measures about one-sixteenth of an inch in length and the full-grown larva about five-sixteenths of an inch. Descriptions of the larval stages, as given by Merrill (21), follow:

First Stage. When the yellowish larva first frees itself from the egg the spines are closely appressed. As the chitin dries, the spines become erect and are seen to be branched at and near the tip. Later the tips of the branches become darker. The larva is about 1.3 mm. long by .6 mm. wide. The body tapers sharply in the abdominal region and is recurved downward. There is a row of four spines across the front of the rather pronounced pro-thorax. On the rest of the body there are six longitudinal dorso-lateral rows, the spines of the outside rows being very small and very few. * * *

Second Stage. After the first moult the larva is 2 mm. long and the tip of the abdomen is slightly more curved than in the first stage. The spines are longer and more branched. The dark tips are not so pronounced. The rows of spines are the same in number but more distinct. * * *

Third Stage. After the second moult the larva is 4 mm. long. The spines are longer, more branched from the sides, and dark tipped. The rows are now easily seen. In this stage the larva seems to be rather humpbacked, the highest and widest portion of the body being about the middle portion. The abdomen tapers sharply, the anterior end slightly, only. * * *

Fourth Stage. At the beginning of the fourth stage the larva is 5.4 mm. long and it increases to nearly 1 cm. in length before the fourth moult. The chief difference between the larva in this stage and in the last is in the size.

THE PUPA.

The pupa (fig. 1, *c*; Pl. V) is ovate in outline, and approximately the size of the adult. It is yellow with brown markings. Anteriorly it is roundedly subtruncate and posteriorly tapers strongly toward the apex. The surface is sparsely beset with bristle-like setæ and long hairs. The head is folded down in front over the thorax and the posterior legs reach below the wing-sheaths. The apex terminates in two elongated processes, conical at the base and black at the extreme tips. The larval exuviae are pushed down and form a protection for the last abdominal third of the body. (Pl. VI.) Length 7-7.5 mm.; width 4-4.5 mm.

DISTRIBUTION.

The bean ladybird occurs in the States of New Mexico, Arizona, Colorado, and Texas. In the last mentioned State it is restricted to localities in the western part. It is also said to occur in Kansas and Arkansas but not as a pest. There is a single record of a beetle, presumably a "chance find," having been taken at Ogden, Utah, but it is not positively known that the species breeds in that State.

The bean ladybird, as has been stated, is to the bean industry in the West what the Colorado potato beetle is to the potato crop in the East, and its origin is obviously the same—Mexico, where it is widely distributed. It is also found throughout Central America. It has been observed at elevations of from 3,000 to 7,000 feet above sea level in New Mexico, and of about 4,000 to approximately 5,000 feet in Colorado.



FIG. 2.—Map showing known distribution of the bean ladybird in the United States, June 1, 1919.

According to the observations of Dr. C. P. Gillette, State entomologist of Colorado, the species inhabits the foothills of the Rocky Mountains, seldom straying far out on the plains, with the exception of down the Arkansas Valley in Colorado. Further details in regard to its distribution in that State are furnished on page 13.

The known distribution of the bean ladybird in the United States is indicated in figure 2.

DANGER OF FUTURE SPREAD.

In regard to the future distribution of this pest it must again be compared with the Colorado potato beetle, first because of its obviously similar origin. It may have been introduced, at an even earlier date than the latter, since the cliff dwellers in the region which the beetle inhabits in the United States included tepary beans

in their dietary. From an economic standpoint it is a potential pest of the type of the Colorado potato beetle and the boll weevil and it is singular that it has never migrated to any noticeable extent as have those pests, since it is probably capable of extended flights. One reason that may be assigned for this is its practical limitation to a single food plant, while the potato-feeding insect infests virtually all of the Solanaceae, including the weeds, and is capable of breeding continuously on all species of *Solanum* and probably on other genera. There is no reason to suppose that this insect may not by flight increase its present range materially some time, although not necessarily in the near future. Its further dissemination, however, would doubtless be slow and never as rapid as in the case of the comparatively fleet-winged and more adaptable Colorado potato beetle. The reasons, then, for its failure to have become more widely distributed are: Its limitation to a single food plant and its probable incapacity for protracted flight with the wind. Moreover, it is probably not capable of inhabiting such varied climates as is the Colorado potato beetle, a species which seems to have no respect for life zones but which thrives equally well from subtropical southern Texas to boreal Manitoba.

In the case of the Colorado potato beetle it can not as yet be definitely stated, as some authors have assumed, that it breeds wherever potatoes are grown, but it is perfectly capable of doing so, and it may be that in the course of time, many years undoubtedly, the bean ladybird will be distributed wherever its food plant is cultivated.¹

Another factor which strengthens the belief that the bean ladybird will, in the course of time, become more widely disseminated is its very close relationship, both structurally and biologically, to the squash ladybird (*Epilachna borealis* Fab.), which ranges from South America northward through Central America, Mexico, and the Antilles, along the Mexican and Atlantic seaboard States to Maine and Canada. Obviously the squash-feeding species has a similar tropical origin, beginning farther southward and extending much farther northward. Instead of progressing straight northward it has followed more nearly the coastal lines and has a totally different distribution in the United States, being somewhat restricted to the East² just as the bean ladybird is restricted to the Middle West.

The present distribution of this species as outlined in the map would indicate that we may expect its establishment some time in the future in near-by counties in the States of Utah, Wyoming, Ne-

¹ The predacious ladybird *Hippodamia convergens* Guér. is capable of accommodating itself to practically all climes and countries, with the exception of areas where the temperature is so high or so low that few forms of plant and insect life are able to survive.

² It occurs, though not as a pest, in certain other regions remote from the region specified, e. g., in Kansas and Arkansas.

braska, and Oklahoma, and later in southern California. There may even exist a wider distribution than is now known in Texas, since the localities inserted on the map plainly show such a possibility.

LIFE HISTORY AND HABITS.

SEASONAL HISTORY.

In the Arkansas Valley of Colorado, and in regions having a similar climate, two generations or "broods" of the bean ladybird develop annually.

The winter is passed in the adult stage, the beetles hibernating under tufts of grass, weeds, old vines, rubbish, and similar material, in or about the fields and gardens in which they developed. The overwintered beetles emerge from their hibernating quarters about the middle of June and, after a brief interval of feeding, mate and begin to deposit eggs.

The first eggs hatch in about a week and the adults of the first generation develop shortly after the middle of July. After an interval of a week or ten days eggs are deposited by the first generation of beetles and from these the first adults of the second generation develop. This occurs during the latter part of August or early September. A portion of the adults of the first generation and all those of the second generation deposit no eggs until June of the following year. The beetles go into hibernation during the last days of September and the first of October and, as previously stated, remain dormant until about the middle of June of the succeeding year.

It is somewhat remarkable that the beetles remain in hibernation during the last days of May and the first half of June when high temperatures, from 90° to 95° F., often prevail.

The egg-laying period of the overwintered beetles, which includes individuals of both the first and second generations, extends from shortly after the middle of June until about the 1st of August, although occasionally some of these beetles live and deposit eggs throughout the summer. The egg-laying period of the beetles of the first generation which deposit eggs during the first season extends from soon after the middle of July until well into September. Reproduction, then, continues from about the middle of June until the beans are destroyed by killing frosts in late September or early October. The insects usually cause a maximum amount of damage during July and August. The larvæ, especially those more than half grown, are voracious feeders and, as a rule, cause vastly more injury than do the beetles.

REPRODUCTION AND DEVELOPMENT.

The life-history studies of the bean ladybird were conducted in Colorado in an open-air insectary at Rocky Ford. The insects were confined in cloth-covered battery jars and fed on the foliage of

string beans. A pair of beetles which developed in late August, 1914, mated August 29 and were isolated. These beetles commenced hibernation October 12, and on November 10 the rearing cage, containing earth and some dead bean leaves under which the beetles rested, was placed in the laboratory cellar. The cage remained in the laboratory cellar until May 20, 1915, when it was again placed in the open air. The beetles emerged from hibernation on June 15, and began feeding. The first eggs were deposited June 18, and from this stock the species was reared for two seasons (1915 and 1916) without a break. The record for 1915 is given in Table I and that for 1916 in Table II.

TABLE I.—*Generations of Epilachna corrupta in 1915.*

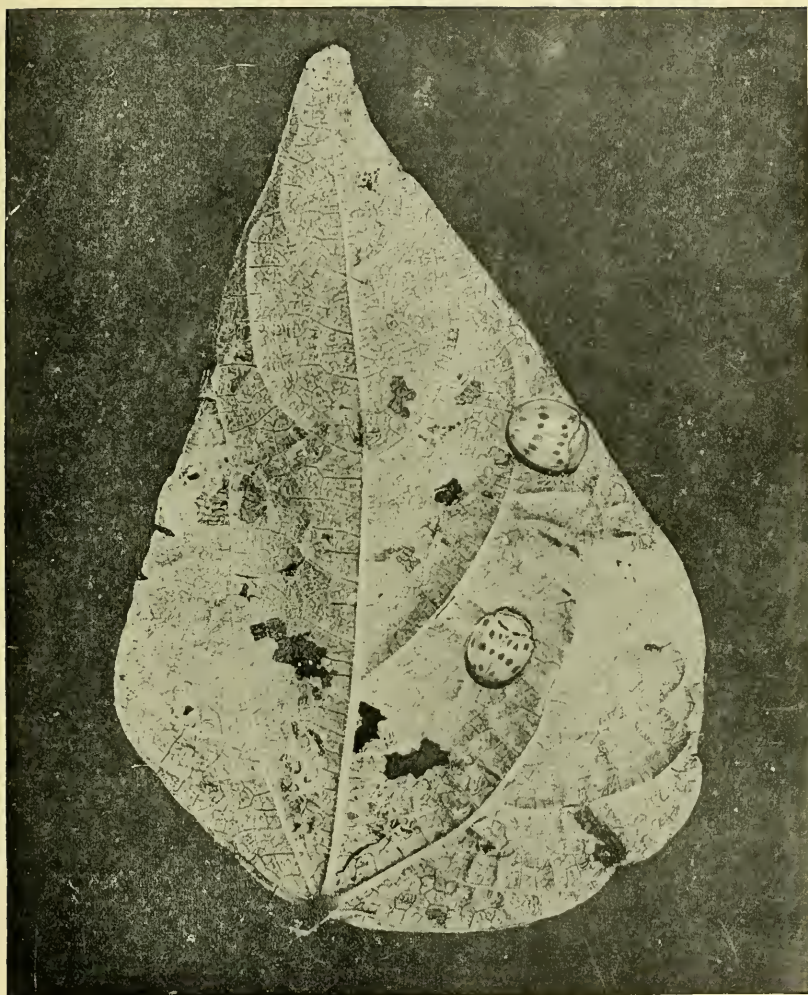
Life-history event.	First generation issued.	Second generation appeared.
Adults developed.....	Aug., 1914	July 19, 1915
First eggs deposited.....	June 18, 1915	July 30, 1915
First eggs hatched.....	June 25, 1915	Aug. 5, 1915
First larvæ matured.....	July 12, 1915	Aug. 23, 1915
First larvæ pupated.....	July 13, 1915	Aug. 24, 1915
First adults developed.....	July 19, 1915	Sept. 1, 1915
	<i>Days.</i>	<i>Days.</i>
Egg period.....	7	6
Larval period.....	18	19
Pupal period.....	6	8
Total duration.....	31	33

TABLE II.—*Record of the generations of Epilachna corrupta in 1916.*

Life-history event.	First generation issued.	Second generation appeared.
Adults developed.....	Sept. 1, 1915	July 17, 1916
First eggs deposited.....	June 18, 1916	July 30, 1916
First eggs hatched.....	June 25, 1916	Aug. 5, 1916
First larvæ matured.....	July 10, 1916	Aug. 21, 1916
First larvæ pupated.....	July 11, 1916	Aug. 23, 1916
First adults developed.....	July 17, 1916	Aug. 31, 1916
	<i>Days.</i>	<i>Days.</i>
Egg period.....	7	6
Larval period.....	16	18
Pupal period.....	6	8
Total duration.....	29	32

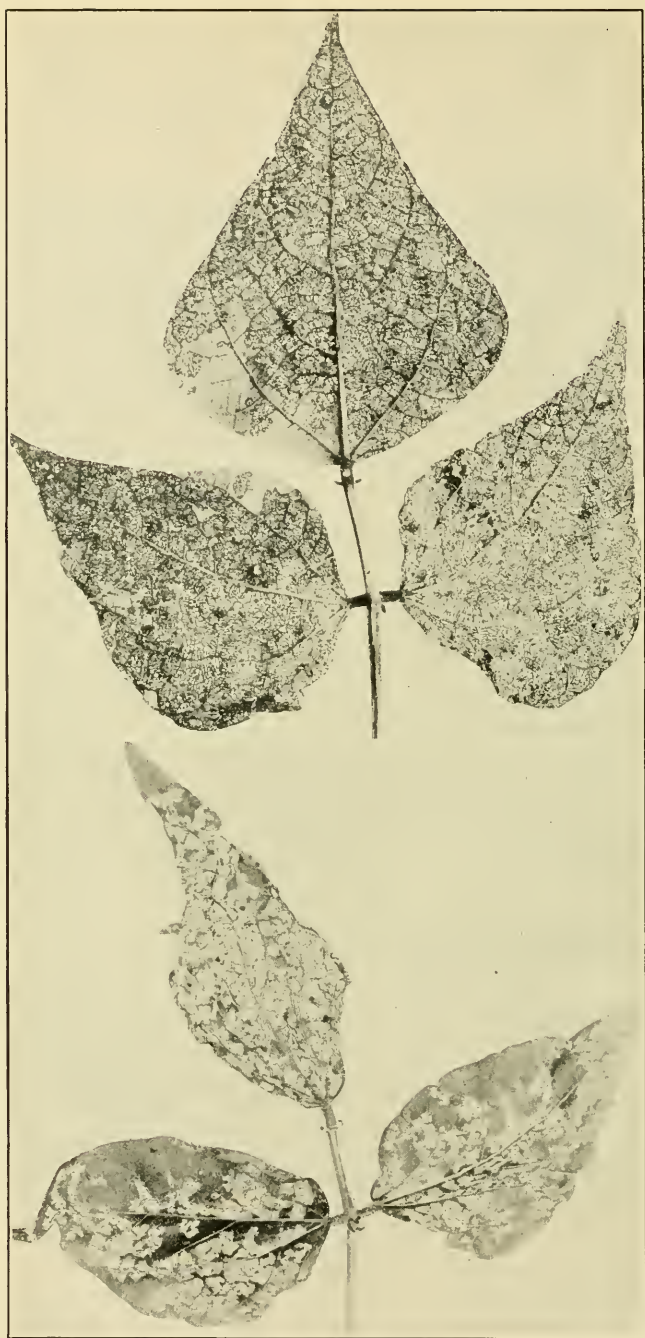
The 19 beetles which developed September 1 fed until September 23, when hibernation began. The cage was placed in the laboratory cellar November 10, 1915, and was removed to the open May 3, 1916. June 12, 16 beetles issued from hibernation, 3 having died during the winter, and began feeding. One pair mated June 13, and the record of the progeny is given in Table II.

The female died September 9. The male went into hibernation October 5, and was later destroyed. In this case the egg-laying



THE BEAN LADYBIRD.

Beetles beginning work on under surface of leaf.



THE BEAN LADYBIRD.

Bean leaves showing injury by beetle.



THE BEAN LADYBIRD.

Bean leaves skeletonized by the bean ladybird. Beetle above; pupæ in middle; larva at left near bottom. Somewhat enlarged.

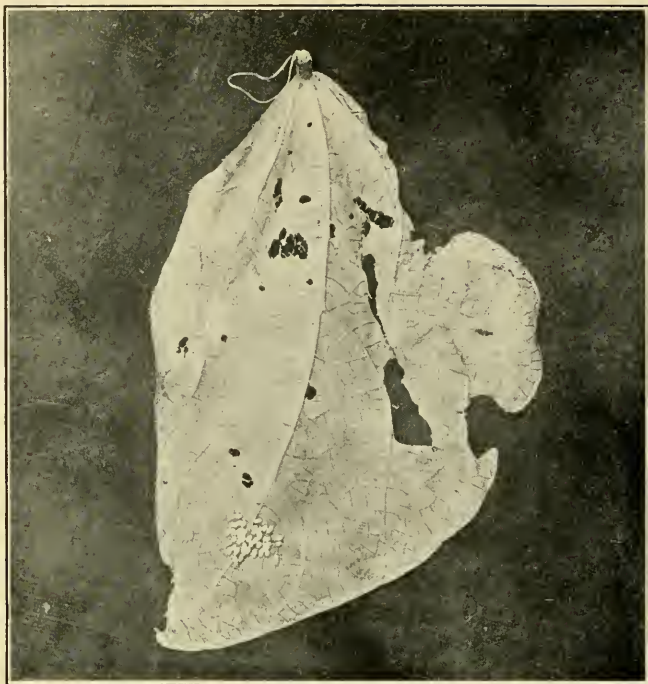


FIG. 1.—EGG MASS ON LOWER PORTION OF BEAN LEAF.

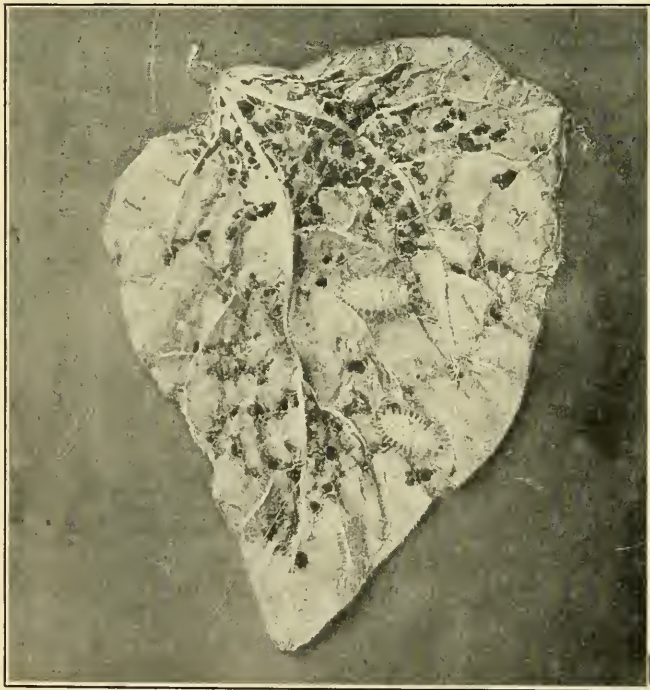
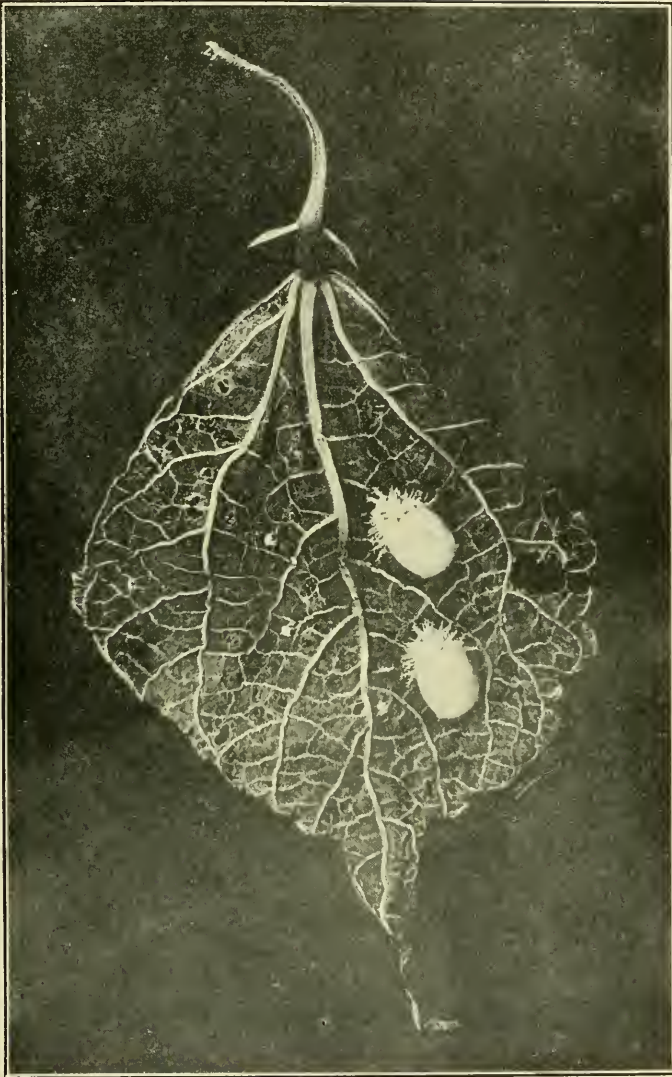


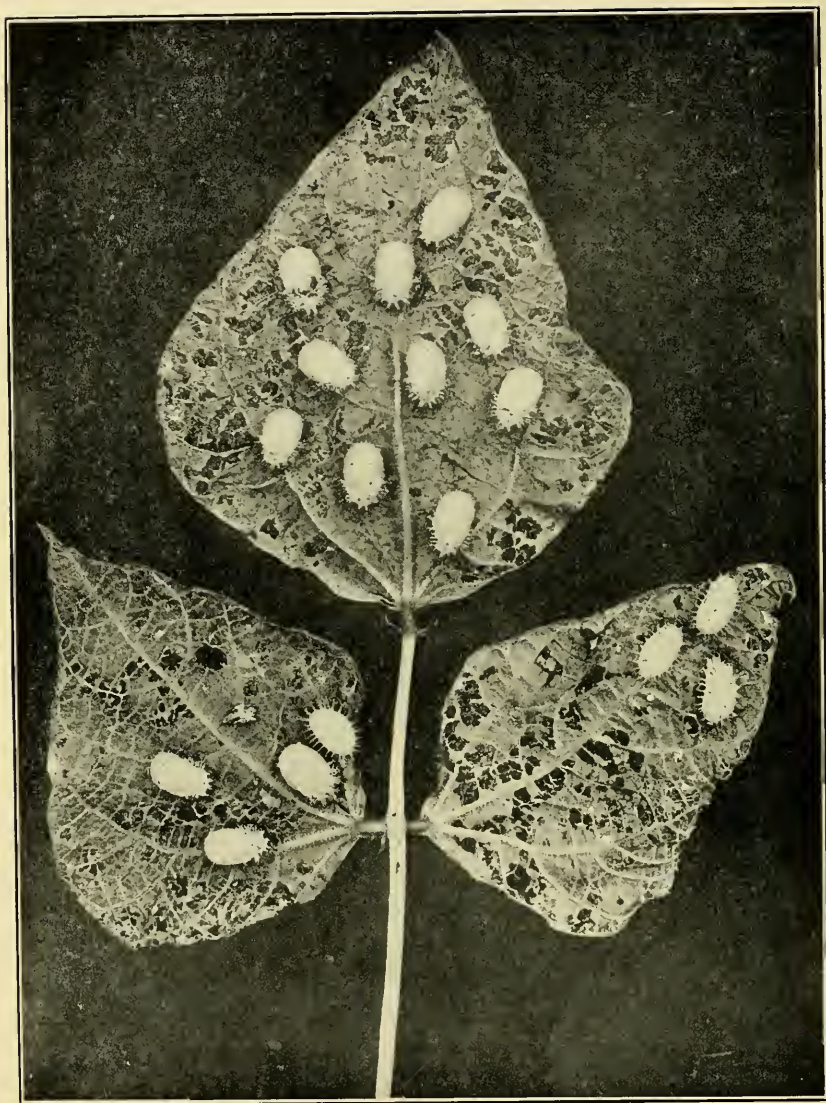
FIG. 2.—LARVÆ AT WORK ON UNDER SURFACE OF LEAF.

THE BEAN LADYBIRD.



THE BEAN LADYBIRD.

Pupæ formed on injured bean leaf.



THE BEAN LADYBIRD.

Cluster of bean leaves showing natural form of pupation on lower surface of leaf, and larva ready to transform on leaf at right.

period extended from July 25 until September 2, a total of 40 days. With other females this period covered from 35 to 70 days.

The life cycle from egg to adult and the periods of the stages by days are given in Tables III and IV respectively.

TABLE III.—*Life cycle of Epilachna corrupta.*

Event.	Date.	Event.	Date.
	1916.		1916.
Eggs deposited.....	Aug. 10	Larvæ molted.....	Aug. 30
Larvæ hatched.....	Aug. 18	Larvæ reached maturity.....	Sept. 3
Larvæ molted.....	Aug. 21	Larvæ pupated.....	Sept. 5
Larvæ molted.....	Aug. 25	Adults developed.....	Sept. 12

TABLE IV.—*Periods of stages of Epilachna corrupta.*

Instar.	Number of days.	Instar.	Number of days.
Egg period.....	8	Fourth larval stage period.....	6
First larval stage period.....	3	Pupal period.....	7
Second larval stage period.....	4		
Third larval stage period.....	5	Total.....	33

The beetles which developed August 31 fed, without mating or depositing eggs, until October 5, when they began hibernation. November 10, 1916, the cage was placed in the laboratory cellar and removed to the open April 17, 1917. The beetles issued from hibernation June 15, 1917, and were then killed, closing the record.

Records of egg-laying were obtained by confining single pairs of beetles, immediately after mating and before the first eggs were deposited, in small rearing jars. The beetles fed on bean leaves and the eggs were removed as deposited and counted. The number of eggs deposited by eight females of the first and second generations were: 504, 552, 616, 636, 850, 942, 1,147, and 1,516, respectively, or an average of 845 eggs to a single beetle.

A detailed record of the female of one of these pairs of beetles, which developed July 17, 1916, and mated July 22, is given in Table V.

TABLE V.—*Egg-laying record of a single female of Epilachna corrupta in 1916.*

Date.	Number of eggs deposited.	Date.	Number of eggs deposited.
1916.		1916.	
July 25.....	52	Aug. 15.....	56
July 28.....	50	Aug. 18.....	58
July 29.....	53	Aug. 21.....	55
Aug. 1.....	52	Aug. 23.....	52
Aug. 3.....	55	Aug. 26.....	52
Aug. 5.....	51	Aug. 28.....	54
Aug. 6.....	53	Sept. 2.....	51
Aug. 9.....	52		
Aug. 11.....	54	Total.....	850

In experiments conducted in New Mexico by Merrill (21) the period of incubation was between 4 and 9 days. The duration of the larval stage was between 15 and 21 days. The pupal period was between 3 and 5 days, and the total developmental period lasted between 22 and 28 days.

HISTORY AND LITERATURE.

The bean ladybird was described by Mulsant in 1850 (1) from Mexico as *Epilachna corrupta* and its injuries were observed in New Mexico at about the same period.

In 1883 Riley (4) published an editorial on this species with quotations from a letter from Prof. George H. Stone, which contains our first known account of the food and injurious habits of this insect. Attack by larvæ and adults was observed on leaves and pods of wax beans at Colorado Springs, Colo., August 26, 1882.

It was not until a lapse of six years that attention was called to further injury by this insect. At that time Judge J. F. Weilandy (5, 6) wrote, July 23, 1889, of injuries at Springer, N. Mex., stating that this "bean bug" committed great depredations in bean fields, often destroying them entirely. The Mexicans had found that late planting, about the middle of July, acted as a preventive of its ravages. In a letter dated July 30, in the same year, he directed attention to injury at Watrous, N. Mex., and stated that the pest had been known in that region for about 40 years. He also furnished specimens from which were recorded, editorially, the habits of two predacious ladybirds, which will be mentioned later under "Natural enemies," of feeding on the eggs of this species.

In 1892 Prof. C. P. Gillette (7) gave an account of this pest in Colorado, furnishing illustrations of the stages and manner of work.

In 1897 Rev. Henry S. Gorham (8) considered this species with the Coccinellidae of Central America, indicating the synonymy, and the distribution in Mexico, Guatemala, and Panama, with notes on variation and colored illustrations of the adult and of the larva. In this year also Mr. H. Griffin (9) reported injury at San Juan, N. Mex. Judge Weilandy furnished a list of the varieties of beans affected and reported on the effectiveness of Paris green which, although it killed the beetles, destroyed the plants as well.

In 1899 Col. Thos. L. Casey (11, p. 103) furnished a characterization of the beetle, comparing it with *E. borealis*. In 1900 Cockerell (13) stated that this species was the "bane of bean growers in New Mexico, from Chicorico Cañon * * * to the Mesilla valley." In 1902 A. N. Caudell (14) cited an instance of extreme injury to beans at Fort Collins, Colo., in 1901. The statement made by W. Knaus (15), in 1906, that this insect was damaging potato near Wootens, N. Mex., is, of course, incorrect. During 1907 Messrs.

Fall and Cockerell (16, p. 170) indicated by localities the distribution in New Mexico. In 1913 Dr. A. W. Morrill (19) published a note on the distribution of this species in Arizona. In 1915 E. O. Essig (20, p. 219) stated that this species was "said to be found in California," which is evidently incorrect as no definite locality is cited and the species is not known to breed in that State. During 1917 D. E. Merrill (21) published the first comprehensive account of this insect, with especial regard to its occurrence in New Mexico, furnishing details in regard to injuries, life economy, and distribution, and indicating methods of control. In most respects the results obtained in that State do not differ materially from those obtained in Colorado.

Popular accounts of the bean ladybird were published by Gillette (10) in 1898, Sanderson (18) in 1912, and by the writer in 1899 (12), 1907 (17, p. 109), 1917 (22, p. 28), and 1919 (23), as well as by others.

UNPUBLISHED RECORDS.

February 2, 1899, Mr. C. B. Metcalfe wrote of the bean ladybird and its injuries to the Mexican Bayo bean or frijole at San Angelo, Tom Green County, Tex. For many years prior to the date of writing growers had not succeeded in raising a crop of beans because of the ravages of this pest, which destroyed the plants by eating the leaves. Metcalfe described the larva as a humpbacked yellow insect about one-fourth inch long and of the color of sulphur, with a hairy-looking covering which changed afterward to the hard-backed grown "bug." He described the larva as destroying the green part of the leaves leaving only a thin tissue. During the same year Mr. James K. Metcalfe, Silver City, N. Mex., wrote that this species was quite injurious to beans in his vicinity, and furnished specimens in different stages. At this time, September 14, larvæ were quite scarce, most of those sent having transformed to pupæ.

August 8, 1904, Oscar Liffreing, Bernardo, N. Mex., sent specimens, mostly pupæ and newly developed beetles, with the report that they were devouring all of the early beans in that region. August 26 of the same year specimens were received from Mr. Liffreing, with report of injury to beans. July 26, 1905, Mrs. V. A. Armstrong reported injury to beans at Fort Collins, Colo., furnishing specimens of larvæ, and leaves and pods showing injury.

September 6, 1908, F. H. Headley reported injury at Fort Collins, stating that this insect was doing a great amount of damage to the bean crop in that section. July 15, 1909, B. F. Morris, Santa Cruz, N. Mex., wrote as follows: "I am sending some chinch bugs, the insect which is working destruction to the bean crop here, and is now depositing its eggs." During 1909 M. C. Stevenson, Espanola,

N. Mex., reported injury, July 24, to beans, furnishing samples of adults. August 11, M. A. Bishop reported injury at Tularosa, N. Mex. He wrote that for two years previously a small yellow bug covered with hairs had been eating the leaves of beans leaving nothing but a bare skeleton. Complaint was also made by Mrs. Katherine Courtney of injury to lima beans at Littleton, Colo.

May 28, 1910, Elias Clark, Alcalde, N. Mex., stated that this insect was very destructive to beans in that vicinity. January 11, 1909, John Block, Santa Cruz, N. Mex., described the larvæ, adults, and the work of this species on beans, requesting a remedy. July 6, 1915, Mrs. Ethel Mercer wrote from Denver, Colo., of little yellow larvæ which literally devoured the bean crop. They began on the leaves, and after these were gone they attacked the pods, as many as 15 being noted on a pod. Before the beans began to bloom the same insect ate the leaves "full of holes."

August 28, 1912, this species, according to Dr. A. W. Morrill, did considerable damage to beans at Prescott, Ariz. At that time it was abundant mostly in the pupal and adult forms. Between July and August of the following year, 1913, much damage was noted to pole beans at Cottonwood, Ariz. The insects practically ruined an entire field of about one-half acre. At that time full-grown larvæ and pupæ and a few egg batches and young larvæ were found. The hibernating adults had disappeared, only newly emerged, pale yellow adults being in evidence.

October 13, 1916, W. E. Marble wrote in regard to the growing of Mexican beans in the Arroyo Animas Valley of New Mexico, stating that the crop was greatly damaged by the larvæ of this ladybird which he described as of about the size of a navy bean, yellow in color, eating the leaves, and leaving only a network. This, he wrote, stops the growth of the plants and ultimately kills them. October 16, A. Warner, Sandy, Ariz., sent specimens, stating that the insect destroyed a crop in about 14 days, and that Paris green was ineffective.

Complaints were made during the year 1917 of injury at Wheatridge, Brewster, Colorado Springs, Rocky Ford, Pueblo, Denver, and Boulder, Colo.; Santa Fe and East Las Vegas, N. Mex.; Flagstaff, Ariz.; and Alpine, Tex. The last report was from T. F. Blaine, dated October 31, and was accompanied by specimens. D. E. Merrill also wrote of this species October 5, 1917, and of its occurrence in the vicinity of El Paso, Fabens, and Clint, in the El Paso Valley of Texas.

F. M. Wadley, scientific assistant, stated June 21, 1918, that the bean ladybird occurred at Wichita, Kans., but was more abundant in the western part of the State. August 6, Thomas H. Hudson complained of injury by this species to beans at Colorado Springs, Colo.

During January, 1919, A. E. Mallory, scientific assistant, wrote in regard to the occurrence of this species at Greeley, Colo., that he had observed the beetles feeding on the underside of the leaves of the mammoth soy bean (*Soja hispida*) in that vicinity. The previous December he found the beetles hibernating under a pile of bean vines. Until the receipt of this last record the species was believed to feed exclusively on table beans.

February 11, 1919, W. A. Williams, Venus, N. Mex., reported injuries by this species to pinto beans in that vicinity. Failure to obtain rain was ascribed as one of the causes of injury. Mr. Williams stated that "on beans these little 'bugs' eat the leaves full of holes and damage the crop considerably." During January and February a number of other complaints were made of injury by this species in New Mexico and Colorado. Other complaints of injury, unaccompanied by specimens, and requests for information in regard to methods of control have been received from other sources, notably Parsons, Kans., Jemez Springs and Nogal, N. Mex., Griffith, Colo., and Kirkland, Ariz.

April 3, 1919, the State entomologist, Dr. C. P. Gillette, collaborator, wrote in regard to the occurrence of this species in Colorado as follows:

We have records of this species from the points which you mention and others near them, and also from Nucla, in the Paradox Valley, Montrose County; from Cortez, in Montezuma County; and from near Greeley, in Weld County. It seems likely that the infestations in the southwestern part of the State are from New Mexico. It has seemed very strange to me that this beetle keeps so close to the foothills, never going out far upon the plains, except down the Arkansas Valley. The beetle was abundant here when I first arrived at Fort Collins, 28 years ago, and it apparently has never occurred as far east as Greeley, about 24 miles from the foothills. I have found it to be a species about equally abundant every year, although there is some fluctuation in numbers. It was very bad last year in the northern section, from Pueblo to Fort Collins, along the eastern foothills, and extended a few miles into the plains.

Writing on this species September 2, 1919, Mr. Fabian Garcia, horticulturist, New Mexico Agricultural Experiment Station, State College, N. Mex., stated that this insect is a serious pest in New Mexico, particularly in the older bean-growing sections, and that it causes the bean growers there a lot of trouble and expense. He expressed the opinion that the losses could be materially reduced by properly spraying.

NATURAL CONTROL.

EFFECT OF CLIMATIC CONDITIONS.

Cold weather appears to be the most important natural check to the development of the bean ladybird in Colorado. This insect is a southern species which apparently has not become fully adapted to

northern climates. This is not a theory but is based on facts. It is indicated by the fact that many eggs, larvæ, and pupæ occur so late in the fall that they are killed by freezing. Many larvæ starve because the foliage of the bean plants on which they had been feeding was destroyed by early fall frosts. It is also not uncommon to find many dead adults in their hibernating quarters where they had been killed by winter temperatures.

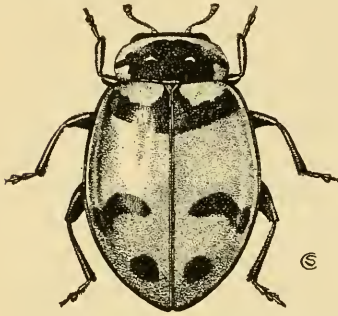


FIG. 3.—The five-spotted ladybird (*Hippodamia 5-signata*), an enemy of the bean ladybird. Enlarged.

NATURAL ENEMIES.

The insect enemies of the bean ladybird are, as far as has been learned, not particularly effective in holding it in abeyance. The beetles are well protected by their firm elytra or wing covers and by a repellent yellow liquid which oozes from their knee joints in

small drops when the insects are disturbed. This liquid possesses a disagreeable odor and doubtless a similar flavor, which, it is believed, may protect the beetles from the attacks of natural enemies.

June 27, 1916, two overwintered female beetles were collected at Rocky Ford, Colo., each with the egg of a tachinid fly attached to one of its elytra. One of these beetles died September 4, and the other September 9. Fertile eggs were deposited at frequent intervals from June 29 until September 5, and no parasites developed. This is the only evidence noted of insect parasites.

Morrill has reported an undetermined ant observed eating the eggs on one occasion.

The adults of three species of predacious ladybirds are known to be natural enemies of this insect. They are: The convergent ladybird (*Hippodamia convergens* De G.); the five-spotted ladybird (*Hippodamia 5-signata* Kby., fig. 3), and the transverse-spotted ladybird (*Coccinella transversoguttata* Fab., fig. 4).

These have been reported as destroying the eggs of the bean ladybird, and next to cold are the most effective known factors in its natural control in Colorado and neighboring States.

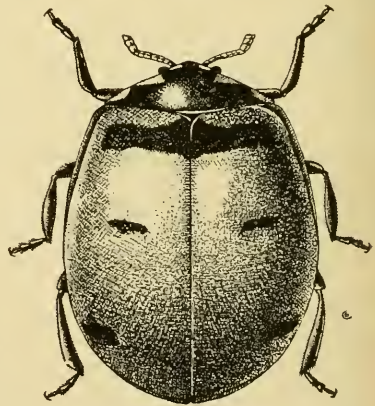


FIG. 4.—Transverse-spotted ladybird (*Coccinella transversoguttata*): Adult beetle. Much enlarged.

The first species occurs in abundance throughout the country and is our most useful ladybird, having been transported from one part of the country to another and to foreign countries. The other two are commonly found in the region inhabited by the bean ladybird, but more especially in the middle Northwest. Both species, however, extend their range to Washington and Oregon.

The larvæ are apparently well protected from insect enemies by the branched spines with which the body is armed. In one case, however, the larva of a lacewing fly (*Chrysopa* sp.) was observed sucking the juices from a partially grown *Epilachna* larva.

No insect enemies of the pupa and no fungous or other disease have been observed to affect the living insect in any stage.

PREVENTIVE MEASURES.

HAND PICKING AND BRUSHING.

The bean ladybird is difficult to control. In small gardens hand-picking the eggs, larvæ, and adults has given satisfactory results. The greatest measure of success has come from gathering and destroying the overwintered beetles soon after their emergence from hibernation and before they have had an opportunity to deposit eggs. The beetles, being sluggish like the Colorado potato beetle, are readily hand picked.

Another method which has afforded some degree of success consists in brushing the larvæ from the foliage to the earth between the rows. This can be accomplished by striking the plants with the bare hand, with a bunch of weeds, or with a paddle fashioned for the purpose from a shingle. If the brushing is done during dry hot weather very few, if any, of the larvæ are able to return to the plants.

CLEAN CULTURAL METHODS.

With the knowledge that the adults of the bean ladybird pass the winter under old vines, tufts of grass, weeds, and other useless material, the numbers of beetles may be materially reduced by burning in late fall or early spring all rubbish of this nature along ditches and fence corners and in similar locations. Everything possible should be done to destroy these winter quarters, as their destruction will afford a considerable measure of protection from injury, if done by a community year after year.

EARLY AND LATE PLANTING.

Proper attention to the time of planting will prevent considerable injury by this as well as many other species of insect pests.

By planting earlier than usual this can be accomplished, as well as by planting considerably later, or as late as a crop can be assured. Since the overwintered beetles do not begin to feed until very late, planting early will accomplish much, enabling the plants to make such good growth that insect damage coming late may be immaterial.

Late planting should be so timed that the plants will come up after the overwintered beetles have about ceased feeding and, at the same

time, early enough to secure a good crop before frost time. No definite time can be assigned for early or late planting for the entire range of this species; it is a matter for the growers themselves to determine. Community work should accomplish much along this line, in determining both the times for planting and the effect of this method.

It has been suggested that early planting be practiced in a community for a series of years and then late planting for a year or two succeeding this.

Whatever can be done toward lessening the number of insects in a community during a given year will have a correspondingly greater effect for the coming season.

DIRECT MEASURES OF CONTROL.

EXPERIMENTS WITH INSECTICIDES.

Numerous spraying experiments were made with arsenate of lead, Paris green, arsenite of zinc, and nicotine sulphate. The experiments were conducted on moderately infested plots of string beans. The spray was applied to both the upper and lower surfaces of the leaves with a portable compressed-air sprayer, fitted with an extension rod, elbow, and disk-type nozzle having a fine aperture.

ARSENATE OF LEAD.

Arsenate of lead was applied at the rate of $1\frac{1}{2}$, 2, $2\frac{1}{2}$, and 3 pounds in powdered form in 50 gallons of water. The spray adhered well and evenly to the foliage, but the effect was very uncertain on the bean foliage as was also the killing effect on the insects. The injury from burning varied greatly with the age and tenderness of the plants, the older, tougher foliage usually escaping appreciable injury, while on the younger, more tender plants the burning effect was serious, especially where the stronger doses were applied.

In summing up the experiments in spraying with powdered arsenate of lead the results were so uncertain that one is hardly justified in recommending this insecticide as a reliable agent for controlling the bean ladybird on string beans.

One experiment was made with arsenate of lead paste at the rate of 6 pounds to 50 gallons of water. This burned the beans so badly that they were almost completely destroyed. Most of the larvæ were killed, but the majority of the beetles escaped injury. This test indicates that paste arsenate of lead is even more injurious to bean foliage than the powdered form, and that the killing effect on the adults of the bean ladybird is equally uncertain.¹

In experiments conducted by Merrill (21) in New Mexico powdered arsenate of lead was used at the rate of 2 and $2\frac{1}{2}$ pounds to 50 gallons of water without damage to the plants. Most of the beetles

¹The tests herein mentioned were conducted with standard or acid lead arsenate. Neutral (diplumbic or triplumbic) lead arsenate, in experiments at Washington, D. C., applied at standard dosage, caused no injury to bean foliage.

left these plants at once. Larvæ hatching from eggs deposited before the application of the poison were also killed where they fed on sprayed leaves. The older larvæ, however, appeared to die of starvation rather than from eating the poisoned foliage.¹

ARSENITE OF ZINC.

Experiments were made with powdered arsenite of zinc at the rate of 1 pound to 20, 30, 40, and 60 gallons of water, respectively. The burning effect on the foliage was in all cases less than where arsenate of lead or Paris green was applied, and usually a larger proportion of the insects was killed. The burning was most apparent about the margins of the holes made in the leaves by the insects in feeding. Many larvæ died after eating the poisoned foliage, but, as with the other arsenicals, the effect on the beetles was uncertain. All factors considered, the most promising results were obtained with zinc arsenite at a strength of 1 to 40. This caused comparatively slight burning and killed an appreciable number of the insects. It should not be overlooked, however, that the killing of the beetles is uncertain and that the burning effect on the plants will vary greatly with their age and tenderness. It is probable that Mexican beans, with relatively tougher foliage, would show less injury from burning than the more tender-leaved string beans treated in these experiments. Zinc arsenite in experiments conducted in New Mexico by Merrill at the rate of 2 pounds to 50 gallons of water produced practically the same results as powdered lead arsenate.

PARIS GREEN.

Experiments were made with Paris green at the rate of 1 pound to 60 and to 80 gallons of water. As a result of these tests the beans were destroyed by burning due to the presence of free arsenic. Most of the larvæ were killed, but many of the beetles escaped. In the face of these results, Paris green at these strengths can not be recommended as a means of controlling the bean ladybird. Everyone who has tried Paris green has experienced the same failure. Sodium arsenite is at least equally dangerous.

SUMMARY OF SPRAYING EXPERIMENTS.

The experience of entomologists in spraying with arsenicals in Colorado and New Mexico tends to show that arsenate of lead acts largely as a repellent rather than as an insecticide, which is true also of its effectiveness in the case of such other pests as the striped cucumber beetle.

Bordeaux mixture, which has come to be considered a standard repellent against flea-beetles, should be tested against the bean ladybird in the future.

¹ Powdered lead arsenate at the rate of 5 pounds to 50 gallons of water was no more effective but did no damage to the plants in experiments made. It should not be used at this strength.

Additional experiments are necessary with arsenate of lead and arsenite of lime, alone and in combination with Bordeaux mixture.

NICOTINE SULPHATE INEFFECTIVE.

In another series of experiments larvæ about one-fourth grown were sprayed with nicotine sulphate at the rate of 1 ounce to 2, 4, and 6 gallons of water, respectively. The larvæ apparently were protected by their spines and the applications were in all cases absolutely ineffective. The only noticeable effect was that the larvæ appeared somewhat stupefied for a brief interval.

COOPERATION.

In the control of this pest, as with so many others which are difficult to destroy, combined effort on the part of the bean growers of the community is essential to success. Whatever can be done in cooperation to lessen the numbers of this insect in one season is felt the next season and if it were rigidly continued would mean the eventual saving of the crop.

SUMMARY OF CONTROL MEASURES.

In the light of our present knowledge the best methods of controlling the bean ladybird may be summarized as follows:

(1) For small gardens and similar areas hand pick the overwintered beetles as soon as possible after they emerge from hibernation.

(2) Brush the larvæ, or young, from the plants during hot, dry weather.

(3) Spray with arsenite of zinc, at the rate of 1 pound to 40 or 1½ pounds to 50 gallons of water, or with arsenate of lead 1 or 2 pounds (powder) to 50 gallons of water.

(4) Clean up the fields by removing dead grasses, weeds, and other possible hibernating quarters during the fall or winter months, and destroy them by burning, or by simply burning over the fields when this practice can be safely followed.

(5) Early and late planting should be practiced. No specific time can be indicated for this that would apply to the entire region which the insect inhabits, and it is more satisfactory for the growers to work out this problem for themselves.

(6) In the case of large areas of beans, close inspection is strongly recommended. Infestation usually begins in small, localized areas, and if these infested spots are located and prompt measures, as indicated in the preceding paragraphs, are taken to destroy the insects a general infestation can be prevented.

GENERAL SUMMARY.

The bean ladybird is a serious pest on beans of all kinds, including the soy bean, in Colorado, New Mexico, Arizona, and western Texas. It frequently destroys entire crops and the conservative estimate of the annual losses incurred is placed at 10 per cent of the crop. This insect feeds normally on the leaves, and attacks also the young pods and occasionally eats into the blossoms. The beetles feed

chiefly on the upper surface, cutting irregular holes in and through the leaves, while the larvæ feed on the lower surface and skeletonize the leaves, seldom cutting through them.

The adult is a robust beetle, about one-fourth inch in length, of oval outline, pale brown, with each wing-cover marked with eight small black spots. The larva is light yellow and armed with branched spines.

The yellow eggs are deposited from about the middle of June until August on the lower surface of the leaves, in clusters of 40 or more, and sometimes to the number of 1,500 by a single female. The larvæ feed at first in colonies, but with larger growth scatter and become more or less solitary. The life cycle may be passed in summer in from 22 to 30 days; the eggs hatch in from 4 to 9 days; the larval period is between 15 and 21 days; and the pupal period varies from 3 to 6 days. In colder weather, however, these periods are longer. Two generations or "broods" are produced annually.

Cold weather in late autumn has the effect of destroying the insects, and their eggs are also destroyed by three species of predacious ladybirds.

In the control of the bean ladybird preventive measures are the most efficient, consisting of hand picking and brushing from the plants, clean culture, and early and late planting. Arsenicals possess some killing properties, but in the main act as repellents. Spraying with arsenate of lead, 1 or 2 pounds (powder), and with arsenite of zinc, 1 to 1½ pounds (dry), to 50 gallons of water, are the most promising. Bordeaux mixture, 4-4-50 formula, should be used alone and in combination with these arsenicals. Additional tests must be made with these substances to ascertain the most effective and economical combination that may be applied to the bean plants without scorching or burning the leaves.

For the treatment of large areas infested by the bean ladybird, a traction sprayer with nozzles arranged for side spraying of the type shown in figure 5 is useful. Owing to the danger of scorching bean foliage, it is desirable that an up-to-date sprayer should always be used.



FIG. 5.—Traction sprayer with nozzle arrangement for side spraying, of type useful for spraying beans for the bean ladybird.

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THE BEAN LADYBIRD IN COLORADO IN 1919.

By A. E. MALLORY, *Scientific Assistant.*

LIFE-HISTORY RECORDS.

Hibernating adults of the bean ladybird which had passed the winter successfully began to appear in Colorado in 1919 about the middle of June, the first individuals having been found June 16 feeding on beans. A week to 10 days later they began to deposit eggs on the underside of the leaves in clusters of about 40 or more. About 2 weeks later, July 9 and 10, the eggs hatched, and the tiny yellow larvæ commenced to feed in a colony near the egg cluster. As they grew older they became separated and did not necessarily confine their feeding to the underside of the leaf. As the season advanced, they fed on every part of the plant, blossoms and pods included. The larvæ were present in all stages from the first appearance until at least September 10. On July 22, which was 10 or 12 days after the eggs had hatched, pupæ were found. During the early part of the season, when foliage is plentiful, pupation takes place on the underside of the leaf. In case the foliage has been extensively destroyed pupation may take place on either side of the leaf or on both sides, 25 to 30 pupæ on a single leaf being not uncommon. As many as 100 on a single leaf were reported in a case where infestation was heavy. This congregating at the time of pupation seems to be characteristic of the species. Pupæ were observed on other plants near beans when the foliage of the beans was almost destroyed.

On July 28 adults of the first brood were observed, and by July 30 they were numerous, gradually increasing in number until about September 1 when they seemed to reach their maximum numbers. The first-brood adults are much lighter in color than the hibernating individuals, being a bright yellow at the time of emergence. They gradually become darker, and at hibernating time some are dark reddish brown, almost if not entirely as dark as the hibernating individuals. Eggs deposited by this new brood were observed August 28 and September 2. It is possible that eggs were deposited by this brood earlier than these dates.

There is no definite place in the life history of this species to separate the different broods. Apparently there are two broods or at least a partial small second brood for this locality. The fact that larvæ were observed in all stages of development during the entire season would suggest two broods. Further, the fact that first-brood adults began issuing rather late, and that so few egg clusters were found in late August and September, would suggest only a partial second brood.

SUMMARY FOR 1919.

Hibernating adults appeared.....	June 16.
Beetles present in large numbers by.....	June 25.
Beetles began depositing eggs.....	June 25.
Eggs began hatching.....	July 10.
Larvæ began to transform to pupæ.....	July 22.
Adults of first generation issued.....	July 28.
Egg clusters, second brood, found.....	August 28.
Maximum numbers first-brood adults observed.....	September 2.
Adults began to become sluggish.....	September 10.
Maximum damage accomplished.....	August 1 to September 1.
Second-brood eggs were probably deposited, but not observed, before August 28.	

INJURY.

The bean ladybird so far as observed confines its feeding to beans, and when taken on other plants is never found feeding. The variety of beans seems to make no particular difference as to susceptibility to attack. The adults do not attack the very young plants to any considerable extent. This fact is probably due to the small number of hibernating individuals. Furthermore, the overwintering adults do not concentrate their attack, but move from plant to plant. Thus the damage is less noticeable. Although the adults usually eat entirely through the leaf, they often merely scrape the surface, leaving a network of veins plainly visible. Later in the season as the foliage begins to die they attack the pods, sometimes completely riddling them, but usually eating out small spherical holes here and there along the pod. In the case of canning beans this injury may cause considerable loss, while on seed beans it is not so serious.

The percentage of injury by a number of adults is small as compared to that caused by an equal number of larvæ. The larvæ begin their attack on the leaves, invariably feeding at first on the underside. Instead of eating through they scrape the surface, leaving the skeleton of the leaf in plain view, although with continued feeding in a limited space they may riddle the foliage.

Maximum damage occurred in this locality during the month of August. This is the period when the new adults are feeding along

with the larvæ, and the two broods of larvæ overlap. Damage was generally worst near fences, along ditch banks, and on beans receiving an extra amount of water by accident or seepage.

There is a large area in northeastern Colorado devoted to farming and stock raising. This area is known as the Greeley District. Beans of all varieties are grown quite extensively. Several thousand acres are planted to beans every year. A conservative estimate of the damage done to the whole bean crop in that district during the season of 1919 by the bean ladybird is about 5 per cent. This estimate at first may seem rather small, but the majority of fields were infested lightly or not at all. In the second place a few fields were more heavily infested than the adjacent or neighboring fields. In those fields coming under our observation the damage by *Epilachna corrupta* varied from an estimated 25 per cent to 65 per cent. One field in particular, of about 15 acres, was damaged at least 65 per cent if not 75 or 80 per cent. No remedial measures were applied in this case.

CONTROL.

In some of the small truck patches the attack of the bean ladybird was controlled by hand picking. In view of the distribution of the damage, as stated, clean farming or destruction of winter quarters is suggested as an important measure of control.

As to remedial measures, all possibilities were not worked out. On July 10 when the first larvæ were observed, the following sprays were tested on large plots in a 9-acre field. Right-angle mist-producing nozzles were used. Approximately 80 per cent of the leaves were covered on one side or the other, the remainder varying from a small amount to none at all. The foliage was heavy.

Experiment No. 1.—Lead arsenate, powder, was used at the rate of 2 pounds to 50 gallons of water, with 2 pounds of hydrated lime added. Very little if any damage was noted from the spray. A few dead larvæ were found.

Experiment No. 2.—Lead arsenate, paste, was used at the rate of 2½ pounds to 50 gallons of water. No damage to the plants was noted.

Experiment No. 3.—Zinc arsenite, paste, was applied at the rate of 2 pounds to 50 gallons of water. This strength caused no damage to the plants.

Experiment No. 4.—Bordeaux mixture, alone, formula 3-6-50, was applied to a plot. No damage was done to the plants. This application seemed to be as effective as any of the foregoing during the earlier part of the season, but this plot showed a greater maximum damage after August 1 than did any of the others. The remainder of the field and a second field of 21 acres were sprayed with

the same material and formula as number 1, viz, 2 pounds of lead arsenate, 2 pounds of hydrated lime, and 50 gallons of water.

Observations following these applications revealed a few dead larvæ. To locate dead larvæ was a difficult matter. Our opinion is that many were killed at the first feeding. If not killed then or very soon after, they fed to maturity. Up to August 1 all remedies tried seemed to be equally effective, the amount of damage to the plant being about the same for each plot. Undoubtedly these insecticides held the beetles and larvæ in check. The 9-acre field had an unusually large number of hibernating beetles. After August 1 the damage seemed to increase quite rapidly, and was worse on the Bordeaux plot than on any of the others. A small unsprayed plot was entirely destroyed, most of the injury here being done before August 1.

A second spraying two weeks later, about July 25, might have almost if not entirely controlled the attack.

In A. B. Owen's field of 9 acres, where spraying experiments were conducted July 10 and 11, the estimated damage was 12.5 per cent. It is believed that approximately 65 per cent of the larvæ hatching before July 25 must have been killed by the lead arsenate or zinc arsenite. The number of adult beetles found in this field in early July undoubtedly was large enough to have damaged the crop to the same extent as in the special field mentioned above. This experiment, while not of the type anticipated, demonstrates that the attack of this species can be controlled by the use of either lead arsenate or zinc arsenite.

A second spraying between July 25 and August 1 is recommended as very promising in controlling the insect, since it is at about this time that the second brood begins to appear. The two broods overlap, and the damage they do begins to increase very rapidly from this time on.

The combination spray consisting of Bordeaux mixture and an arsenical is also a promising experiment. Undoubtedly the Bordeaux mixture, in case it proves a repellent against this insect, will serve as an important fungicide. It will add very little to the expense of spraying, and will possibly increase the yield several bushels per acre by controlling minor fungous diseases.

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BULLETIN No. 847

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.

PROFESSIONAL PAPER

August 9, 1920

ROUNDHEADED APPLE-TREE BORER:
ITS LIFE HISTORY AND CONTROL

By

FRED E. BROOKS, Entomologist,
Deciduous Fruit Insect Investigations

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INTRODUCTION.

In the spring of 1911 a field station of the Bureau of Entomology was established at French Creek, W. Va., and a study begun of the roundheaded apple-tree borer in connection with a general project on boring insects attacking deciduous fruit trees. The work was under the direction of Dr. A. L. Quaintance and was placed in charge of the writer, with whom was associated, in 1911 and 1912, E. B. Blakeslee, of the Bureau of Entomology. During the summers of 1915, 1916, and 1917 C. R. Cutright was employed temporarily to assist with the investigation.

The field station is located in a hilly, partly wooded region where small orchards, wild seedling apple trees, and native host trees of the borer abound and where the insect itself is plentiful. For rearing purposes and the testing of control measures, 1,000 3-year-old apple trees, of the varieties known as King, Grimes, and York Imperial, were planted in the adjacent locality of Elkins, W. Va., on land leased for the purpose. In addition to the work at the two points mentioned, rearing and life-history studies were conducted at Pickens, Weston, and Great Cacapon, W. Va., and at Demorest, Ga.,

¹ *Saperda candida* Fabr.; order Coleoptera, family Cerambycidae.

Biltmore, N. C., Winthrop, Me., and Munising, Mich. First-hand observations on the species were made also in many other localities and more or less original data obtained therefrom. The studies were continued over the period 1911 to 1918.

HISTORY.

The roundheaded apple-tree borer was first described by J. C. Fabricius in 1787 (1)¹ as *Saperda candida*. In 1824 it was redescribed by Thomas Say (2) as *Saperda bivittata*, and by this name it was commonly referred to by Harris, Fitch, Walsh, and other early American writers on economic entomology. From 1875 to 1885 Riley, Lintner, and others recognized the priority of Fabricius's name, and since that time the species has been rightfully designated *Saperda candida*.

The insect is native to North America and originally fed upon and bred within a limited number of forest trees and shrubs belonging



FIG. 1.—Distribution of the roundheaded apple-tree borer (*Saperda candida*).

to the family Rosaceae. When cultivated orchards of apple, pear, and quince began to be established in the eastern part of the United States the borer soon found its way from the forests into the orchards and did much damage to valuable fruit trees. There are

many records of serious injury in New York and throughout the New England States, beginning as early as 1825. Apple trees seem to have suffered most; in some cases entire orchards were destroyed, and the loss of 50 per cent of the trees was not unusual. Felt and Joutel (6) cite numerous historical references showing the widespread and destructive nature of the insect in the days of pioneer orcharding in this country. In more recent times, as the orcharding interests of the country have developed, losses from this insect have increased rather than diminished. At the present time it is an orchard pest of primary importance throughout a great portion of the apple-growing region east of the Rocky Mountains.

DISTRIBUTION.

The known range of the roundheaded apple-tree borer may be bounded by a line extending from near the mouth of the St. Law-

¹ Numbers in parenthesis refer to "Literature cited," p. 41.

rence River westward through Quebec and Ontario to Minnesota, thence in a southwesterly direction through Nebraska, Kansas, and New Mexico to Texas, and thence eastward through Texas, Louisiana, Mississippi, Alabama, and Georgia to the Atlantic coast. (See fig. 1.) There seem to be no data showing that the general range of the species has been greatly extended by the development of the orchard industry of the country.

Within the bounds of its range there are many limited districts where the borer does not occur, or, at least, where it is very uncommon. Just why this is true can not be fully explained, but the absence of native host trees and the abundance of those species of woodpecker which prey upon the borers are two factors which often have much to do with the local scarcity of the pest. Areas of comparative freedom and corresponding areas that are heavily infested often exist near together for years at a time with little relative change. This occurs in native woods as well as in orchards. The peculiarity may be partly explained by the tendency of the species to colonize or form family breeding centers, far from which the adult females do not habitually wander.

FOOD PLANTS.

Probably no other tree is so subject to attack by this borer as the quince. Wherever the borer is common it is difficult to succeed with this fruit. Quince trees are usually small and one or two borers can injure greatly or kill a tree in a single year. The habit which the quince has of sending up suckers or sprouts around the central stem tends to give the borers a good chance to work. In the bases of such clumps borers are hard to reach in the worming process and there they may find positions where woodpeckers can not get at them. Apple is undoubtedly the second choice, and probably mountain ash (*Sorbus americana*) is next in favor. Of the cultivated fruits, quince, apple, and pear are preferred in the order named. Mountain ash, service (*Amelanchier canadensis*), wild crab (*Pyrus* spp.), hawthorn (*Crataegus* spp.), and chokeberry (*Aronia* spp.) are native hosts which are attacked about in the order stated. There are records in the Bureau of Entomology of the development of this borer in peach, but it is certain that this tree is very rarely attacked.

In one instance in West Virginia all the host trees of this borer which grew on a certain tract of woodland and grown-up field were cut and examined to determine the relative extent of infestation of each species of tree. The trees examined numbered 1,483 and the results of the count are given in Table I. It is probable that in any adjacent locality a considerable variation from these figures might have been found, yet the results of the count showed what is ap-

parently a constant preference for apple over the other species of host trees present in this instance.

TABLE I.—*Relative numbers of roundheaded apple-tree borers found in different species of host trees at French Creek, W. Va.*

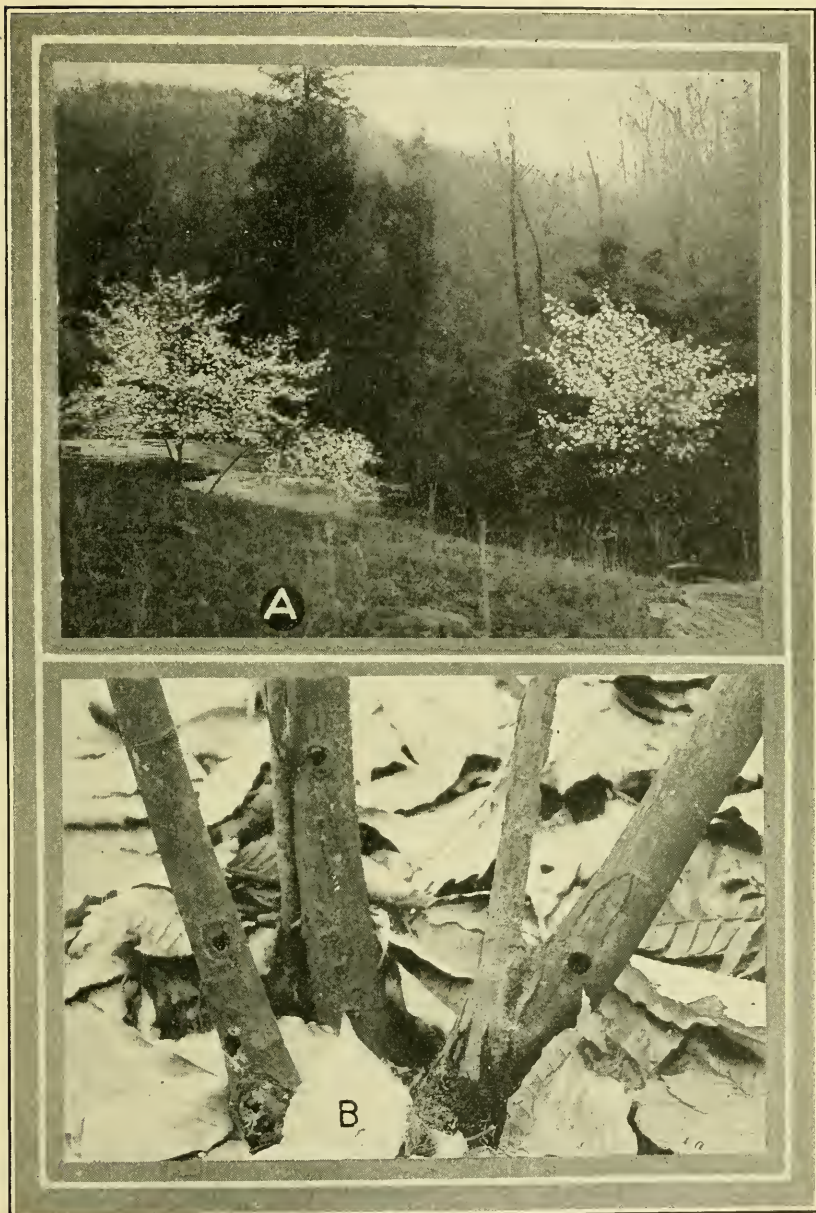
Trees examined.		Number of borers.
Number.	Variety.	
194	Seedling apple.....	85
11	Pear.....	0
823	Wild crab.....	9
405	Hawthorn (<i>Crataegus</i>).....	1
50	Service.....	0
1,483	Total.....	95

It will be noted from Table I that in this case the 50 service trees (Pl. I) examined contained no borers. This is far from the rule as regards the service, for in woods where that tree and mountain ash abound tracts are often found where practically every tree is infested. (Pl. I, B.) Other areas near by of equal size are quite likely to occur where no borers can be found, although the host trees may be just as abundant as where infestation is general. This arises from the fact that under natural conditions families or communities become established and reproduce through many generations within restricted areas. It is probable that adult males fly readily from one breeding center to another, preventing thereby an excess of interbreeding, but the females do not normally tend to go far from the tree in which they developed, provided other host trees are near. This tendency for infestation to be confined to limited groups of trees is often noted in cultivated orchards. Isolated trees are sometimes attacked, however, and there is no question that the female is capable of flying to a considerable distance when impelled by a scarcity of trees in which to oviposit.

DISTRIBUTION AS AFFECTED BY NATIVE HOST PLANTS.

As has been pointed out, the principal native host trees of the roundheaded apple-tree borer are the service, mountain ash, wild crab apple, and hawthorn. Of these wild hosts service and mountain ash seem to be preferred to the others. It is an interesting fact that the service tree (Pl. I, A) occurs over practically the same region of North America as does the insect in question.

These wild food plants undoubtedly play an important part in the local and general distribution of the borer. Infestations commonly attributed by orchardists to certain soil conditions, to newly cleared land, or to the hilly contour of the land are in reality usually due to



ROUNDHEADED APPLE-TREE BORER.

A, Blooming service trees, *Amelanchier canadensis*. At this season of the year borers are undergoing transformation to beetles. B, Exit holes of beetles in clump of young service trees.



ROUNDHEADED APPLE-TREE BORER.

Wire-screen cages used on infested apple trees to hold escaping beetles.

the proximity of the insect's breeding places, the breeding places quite often consisting of these wild host trees that thrive on account of favorable soil, elevation, or other local conditions. Orchards established on newly cleared lands and in hilly locations are more likely to have woods or neglected thickets of wild crab apple, seedling apple, or hawthorn growing near to them than are orchards in the more valuable and highly cultivated valley or level lands. The wild host trees that grow in the woods and thickets (Pl. I) are usually breeding places for the borer, and the adult insects that develop within them fly to the orchards near by and deposit their eggs. In some localities of the Shenandoah apple region the idea is prevalent that borers discriminate between soils and prefer the shale lands of the hills rather than the clay and loam of the valleys. The greater abundance of borers in hill orchards, however, can be explained by the prevalence in such localities of the wild trees in which they breed (Pl. VII, C), the soil having only the indirect bearing on the situation that the shale lands favor the growth of service and other wild host trees.

The native service tree (Pl. I) is perhaps the most effective distributor of this insect. In about 25 localities within the States of Maine, Michigan, Pennsylvania, West Virginia, Virginia, North Carolina, Georgia, Alabama, Mississippi, and Florida, where careful investigations were made, the absence, scarcity, or abundance of service trees was accompanied by a corresponding absence, scarcity, or abundance of the roundheaded apple-tree borer.

CHARACTER OF INJURY.

About 95 per cent of the eggs (Pl. IV, B, C, E) of this borer are deposited within the bark at the base of the tree trunk. (Pl. III.) Usually the eggs are within 6 inches of the ground, but occasionally they are placed in a crotch of the tree or even in a branch 10 or 15 feet above ground. The larva (Pl. V, A, B; VIII, A), which hatches in early summer, feeds at first on the inner bark, eating out a roughly circular space about the oviposition scar and ejecting stringy, sawdustlike castings of a reddish color through small openings in the outer bark. (Pl. V, C.) As the larva develops it extends its gallery either up or down the tree or transversely with the grain of the bark and before the end of the first season may burrow into the wood. (Pl. V, A, B.) More frequently, however, it spends the first winter in the inner bark and enters the wood the second summer. The burrows, both in the bark and wood, are broad and irregular in form, and, with the exception of a space about the borer (Pl. VI, D), are packed with digested wood particles (Pl. VII, A, C). The borer feeds from about the blooming time of apple in the spring until late

in the autumn and continues to throw out castings until it begins the construction of its pupal quarters. (Pl. VII, A.)

Trees of all ages are attacked, but the most severe injury is done to young trees, in which the wound made is greater in proportion to the size of the trunk. (Pl. IV, D.) Frequently a number of borers will attack a single tree and girdle it completely or so riddle and weaken the heartwood that the tree will break over at the surface of the ground. It is not unusual to find a dozen borers in one tree, and on one occasion the writer found 25 within an 8-year-old apple tree. Felt and Joutel (6) cite an instance where 30 borers were removed from one tree.

Trees severely injured by borers present a sickly appearance, the foliage being sparse and of a pale green color. (Pl. VI, A.) When of bearing age they are inclined to bloom freely and set heavy crops of fruit, the fruit developing poorly and the trees often dying in an effort to bring the crop to maturity. If any part of an orchard is bounded by woods the first and most severe injury usually occurs among trees near to such woods.

METHODS USED IN SECURING BREEDING MATERIAL AND REARING THE INSECTS.

In the rearing work connected with this investigation many individual insects were carried through from eggs to adults in young apple trees planted for the purpose. Larger apple trees were used in which to plant newly hatched borers for rearing purposes. The trunks of some trees were made to support and bring to maturity as many as 25 borers. Each spring a large number of pupæ were secured by scouring the roadsides, grown-up fields, and neglected orchards of various localities for small, worthless seedling-apple trees in which the insects were maturing. Such trees were cut near the ground and short sections of the base of the trunk containing the pupæ sawn off and taken to the insectary, where they were kept in rearing cages. Many pupæ were also chiseled out of trees and placed in small glass vials excluded from the light. About 75 per cent of the pupæ kept in the vials developed into normal adults.

CAGES USED FOR REARING AND OBSERVING BORERS.

In carrying on the work herein described three types of fine-meshed, wire-screen cages were used. The first were small cylinders fitted around the bases of trees in which borers were developing (Pl. II). These cages were about 15 inches in length, the lower end when in place being sunk in the earth for half an inch and the space at the top between the wire and tree packed with cotton batting. Such cages excluded woodpeckers, imprisoned emerging beetles, and

were useful in other ways in preventing the disturbance of the insects. A larger form of cage was made by stretching wire over a light wooden frame 2 by 2 by 4 feet in dimensions. Cages of this type were used to set over apple trees 3, 4, or 5 years of age that had been headed low and pruned in for the purpose. When in place these cages were mounded slightly with earth at the bottom to prevent the escape of the beetles and were secured from wind by being attached with screws to posts driven into the ground at the corners. In these cages many beetles were confined over growing trees, and, so far as could be observed, lived lives comparable in length with those in the field. Several other cages of larger size were built over clumps or short rows of young apple trees. Some of these cages were 20 feet in length by 8 feet wide and 8 feet high. They were provided with tight-fitting doors large enough to admit a man and were used for observations on the various stages of the borer and for testing control measures.

THE EGG AND OVIPOSITION.

THE EGG.

The egg (Pl. IV, B, C, E) when first deposited is yellowish white, assuming a darker shade within a few days. It is 3.5 to 4 mm. in length by 1 to 1.5 mm. in width, slightly flattened, both ends tapering to rounded points, the shell tough and plastic, bending somewhat in conformity to the space which it occupies. There is considerable variation in size and shape.

THE OVIPOSITION PROCESS.

Egg laying usually begins a week or ten days after the female beetles leave the wood. In preparing to oviposit, the female assumes an oblique position on the bark (Pl. III, A) and with her jaws makes a slightly curved slit in the bark 4 or 5 mm. in length, and usually extending parallel with the grain of the bark. (Pl. IV, A.) After the incision is completed, the beetle turns, inserts the tip of the ovipositor into the opening, and with considerable effort forces it into the tissue, usually between the bark and wood. (Pl. IV, B, C.) The ovipositor is inserted at about the center of the slit made with the mandibles and is extended under the bark in a direction at right angles to the slit. The egg is placed with the end toward the slit and from 1 to 2 mm. from it at the nearest point. After the ovipositor is withdrawn a small mass of clear, gelatinous liquid is ejected into the hole, which dries and seals the egg chamber. Two or three minutes are spent in making the initial slit and twice that time in inserting the ovipositor, laying the egg, and sealing the

opening. Several eggs are usually deposited at a time within one tree (Pl. IV), quite often the second slit in the bark being made joining and in line with the first. When the bark over eggs is peeled off the eggs adhere to the bark rather than to the wood. (Pl. IV, B, C.)

After the batch of eggs is deposited the beetle may crawl up the trunk to the branches or may move away on the ground for a little distance and then take wing.

TIME OF DAY DURING WHICH EGGS ARE LAID.

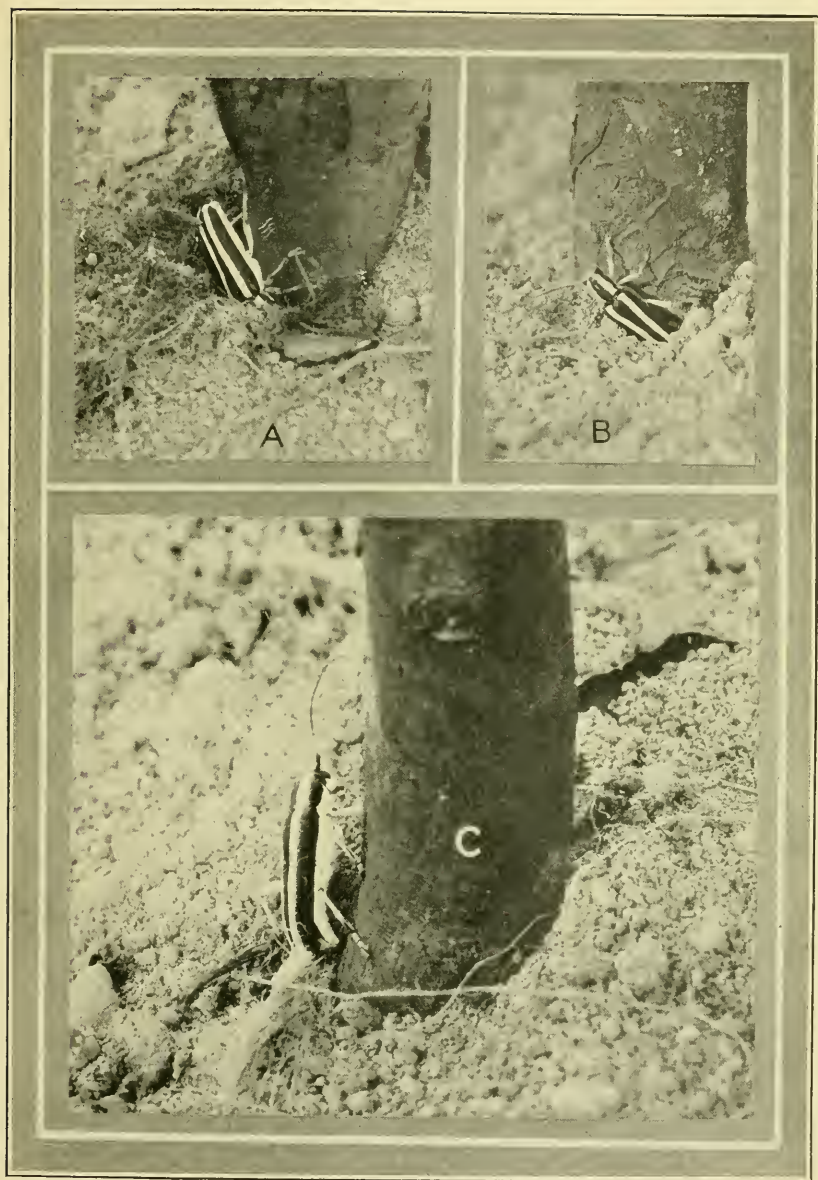
Most of the eggs are deposited during the hotter part of warm, sunny days. No evidence was obtained that oviposition ever takes place at night. In one case a female was found ovipositing at 5.30 a. m. and others were several times observed laying eggs near twilight in the evening, a time of special activity with both sexes of beetles.

PLACE OF OVIPOSITION.

As has been stated on another page, probably 95 per cent of the eggs of the roundheaded apple-tree borer are deposited in the trunks of trees within 6 inches of the ground; usually they are not more than 1 or 2 inches above the soil and quite often they are on a level with (Pl. III, C) or slightly below the surface. (Pl. III, A, B.) In rare instances eggs are deposited in the crotches of trees, around the edges of cavities in the trunk or larger branches, and even in small branches high up in the trees. In one case the writer found two larvæ working in a branch 15 feet above the ground. Usually woodpeckers remove the borers that begin operations aloft in the trees. Possibly the beetle's habit of ovipositing close to the ground has evolved from the greater dangers attendant upon the higher locations.

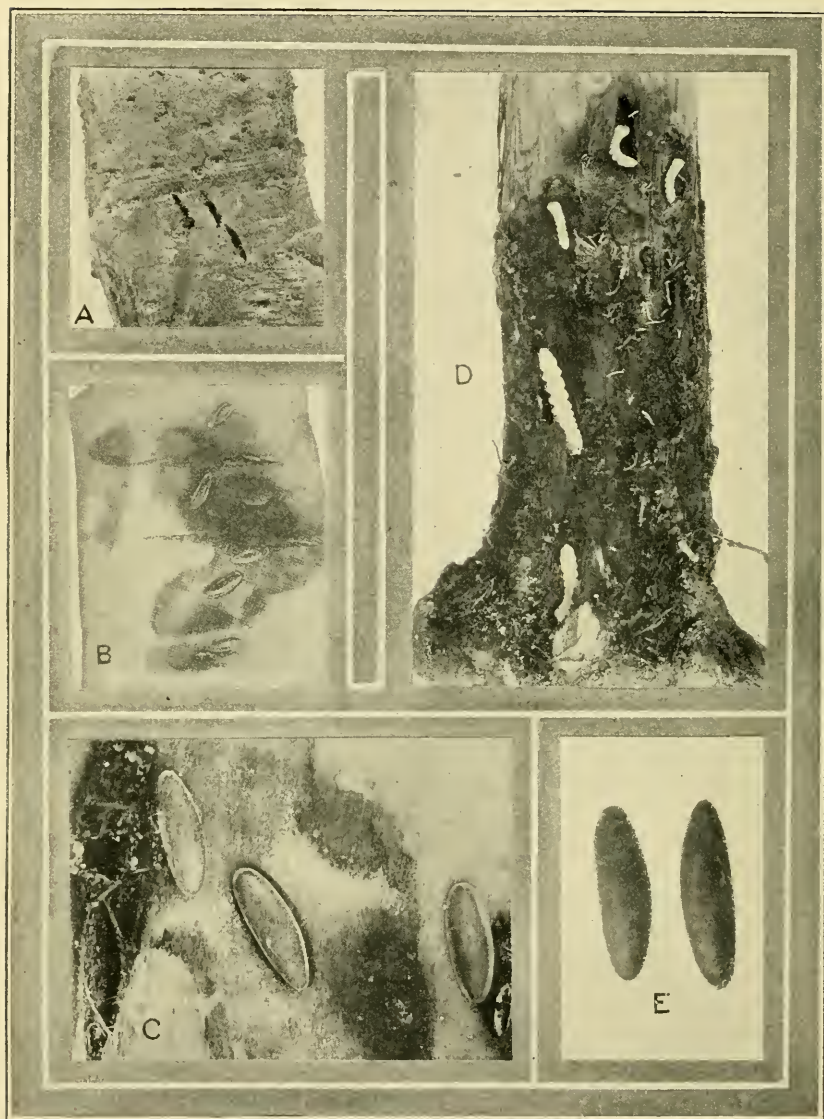
When the female beetle is ready to oviposit she usually crawls from among the branches downward along the trunk. In descending, if an obstacle of any kind is encountered she may pause and oviposit in the bark above it. This habit accounts for borers occasionally found in the crotches of trees. The writer found numerous eggs and larvæ above burlap bands which had been placed around the trunks of apple trees for trapping codling moth larvæ. When similar bands were placed on trees in cages the beetles laid more eggs above the bands than at the ground. In one test of this kind, comprising 5 trees and 5 female beetles, 36 eggs were laid above the bands and only 15 at the ground below the bands. These bands were attached around the trunks about 15 inches up from the ground.

The statement has been made that the females prefer to oviposit in the trunks of trees that are surrounded and shaded by weeds,



ROUNDHEADED APPLE-TREE BORER.

A, Female beetle splitting the bark of a young apple tree just below the surface of the ground preparatory to depositing an egg. Natural size. B, Female beetle placing an egg in the tree just below the surface of the ground. Natural size. C, Female beetle ovipositing at the surface of the ground. Slightly enlarged.



ROUNDHEADED APPLE-TREE BORER.

A, Oviposition scars in bark of young apple tree. Natural size. B, Inner surface of bark peeled from young apple tree, showing position of eggs. Natural size. C, Eggs in natural position. Much enlarged. D, Young borers attacking lower trunk of young apple tree. E, Eggs. Much enlarged.

litter, or water sprouts, and that trees so surrounded are more likely to be injured by borers than those having trunks exposed to the full light. Observations made by the writer, however, indicate that the beetles prefer to oviposit in the sunlight rather than in the shade. In one case 609 borers were removed from an orchard of 6-year-old apple trees which was located on a hillside having a general slope to the southwest. The trunks of the trees were long and one side received the unobstructed sunlight during a greater part of the day. The oviposition scars in which the borers hatched were found and those situated on the sunny side and shady side of the trunks were counted separately. As nearly as possible, each side was made to include half the circumference of the trunk. Of the 609 oviposition scars which were located, 393 were on the sunny or exposed side and 216 on the shaded side. The fact that about 65 per cent of the eggs had been laid on the more exposed side of the trees indicates that mulches of straw or hay placed around trees or the shading of the trunks by low branches does not attract the beetles, but rather repels them.

OVIPOSITION IN CAGES.

Other workers with this insect seem to have had but little trouble in inducing caged female beetles to oviposit in apple twigs, in sections of apple branches set in the ground, and even in apple fruits. The writer, however, has never been able to get a normal frequency of oviposition in any but growing trees. At one time 15 pairs of beetles were confined separately in roomy cages for a period of 17 days. Fresh apple branches, about an inch in diameter, were set in the ground daily in each cage. Although this was kept up from May 31 to June 17, a time when egg laying in the field was at its height, only 17 eggs were secured in the branches and 10 of the 15 females failed altogether to oviposit. The cages with the beetles were then removed and placed over small growing apple trees, whereupon oviposition began freely and at once. Attempts to induce caged females to oviposit in other than growing trees were made frequently, but never with entire success.

OVIPOSITION PERIOD.

As an example of the period of time over which eggs are deposited in a given locality, observations made in 1914 may be cited. During that year the first female issued on May 23. Eight days later she paired with a male and on June 4 laid her first eggs. No record was obtained of the last egg of this individual but other females continued to oviposit until August 1, the entire egg-laying

period for the year covering 58 days. It is not unusual to find unhatched eggs in the field in the latitude of West Virginia from August 10 to 15, although none have been found after August 15. From these and from considerable other data obtained, it appears that normally egg laying continues in a given locality from 50 to 60 days, although perhaps no single individual oviposits over so long a period of time.

INDIVIDUAL EGG CAPACITY.

The number of eggs normally deposited by a single female beetle is not great, the average number having been found by different investigators to vary considerably. Felt and Joutel (6) mention 10 as being about the quota for one individual, while Becker (14), making observations in the Ozark Mountain regions, found the number to range from 16 to 93, with an average of 40.8 per female for five individuals. The writer obtained egg counts from 15 individuals, the figures being shown in Table II.

TABLE II.—*Individual egg capacity of female beetles of the roundheaded apple-tree borer at French Creek, W. Va.*

Year.	Number of females.	Number of eggs.	Average number of eggs per female.
1911.....	3	52	17.3
1914.....	1	17	17
1914.....	1	20	20
1914.....	1	22	22
1912.....	1	13	13
1912.....	1	20	20
1914.....	7	193	27.6
Total.....	15	337	.....

Average number of eggs per beetle..... 22.5

Table II shows that the minimum and maximum numbers of eggs obtained from 15 beetles were 13 and 27.6, the average being 22.5. Since these records were obtained in several different years under conditions that were approximately normal they probably represent fairly accurately the average number of eggs laid by females in the locality mentioned.

PERIOD OF INCUBATION OF EGGS.

The time required for the eggs to hatch has been variously stated at from 8 days to 3 weeks. The writer noted the period in 8 instances, the data for which are set forth in Table III.

TABLE III.—*Period of incubation of the roundheaded apple-tree borer at French Creek, W. Va.*

Dates on which eggs were laid.	Dates on which eggs hatched.	Number of eggs.	Number of days required to hatch.
June 14.....	June 28.....	1	14
June 12.....	do.....	1	16
June 9.....	June 25.....	1	16
Do.....	June 26.....	1	17
June 10.....	June 23.....	1	13
June 13.....	June 29.....	1	16
Do.....	June 30.....	1	17
Do.....	July 2.....	1	19

Average period of incubation..... 16 days.

As is shown in Table III, the minimum and maximum periods of incubation were 13 and 19 days, the average for the 8 eggs being 16 days. Evidence was obtained that hatching is retarded by low and accelerated by high temperatures.

THE LARVA.

The larva (Pl. V, A, B) is a cream-colored, footless grub, with brown head, blackish mandibles and a conspicuous patch of small, brown tubercles on the posterior half of the broad, flattened dorsal surface of the first thoracic segment. The intersegmental constrictions are deep and the dorsal and ventral surfaces of the first seven abdominal segments are elevated and roughened. The sides of the body are sparsely covered with short, stiff hairs. When full grown, the length is from 30 to 40 mm., the females being considerably larger than the males. According to Becker (14) there may be as many as six larval instars.

DEVELOPMENT AND FEEDING HABITS OF THE LARVA.

The behavior of the larva varies as affected by individual characteristics, difference in size, vigor, and species of host trees, and difference in localities, so that no one description of the larval development will apply to all. In the latitude of West Virginia the activities and growth of the larva when feeding under normal conditions in apple are about as follows: The larva begins to feed at once after leaving the egg and soon eats out a broad, irregular, usually more or less circular burrow around the point where the egg was laid. At this stage of its life growth is rapid and the borer soon forms a broad, elongate gallery under the bark which may extend in any direction away from the point first attacked. As winter approaches there is some tendency to burrow downward to or beneath the soil, but this is by no means general.

At first the feeding is all in the bark and the point of injury usually shows from the outside as a dark, slightly depressed spot from

which castings are ejected and from which a small quantity of sap often flows. In some cases the borer burrows into the wood the first season, but usually it does not enter the wood until the succeeding spring. In small trees the galleries penetrate to the heart, but in old trees they are seldom extended more than an inch beneath the inner bark. The burrows in the wood, like those in the bark, are broad and irregular in shape and usually extend both above and below the surface of the ground. In the northern part of the insect's range a greater proportion of the feeding seems to take place beneath the ground. The writer found larvæ in Maine burrowing downward in the roots to a distance of a foot or more from the base of the trunk, a depth which does not seem to be reached in the South. Many 1-year-old larvæ were also found in Maine that had not yet penetrated into the wood but were still feeding in the bark near the old oviposition scars. In all their feeding larvæ keep an open space about themselves, to allow of free movement, but pack the balance of their burrows with wood fragments. Strings of reddish-brown castings are also thrown out from the tree through small openings in the bark. (Pl. V, C.)

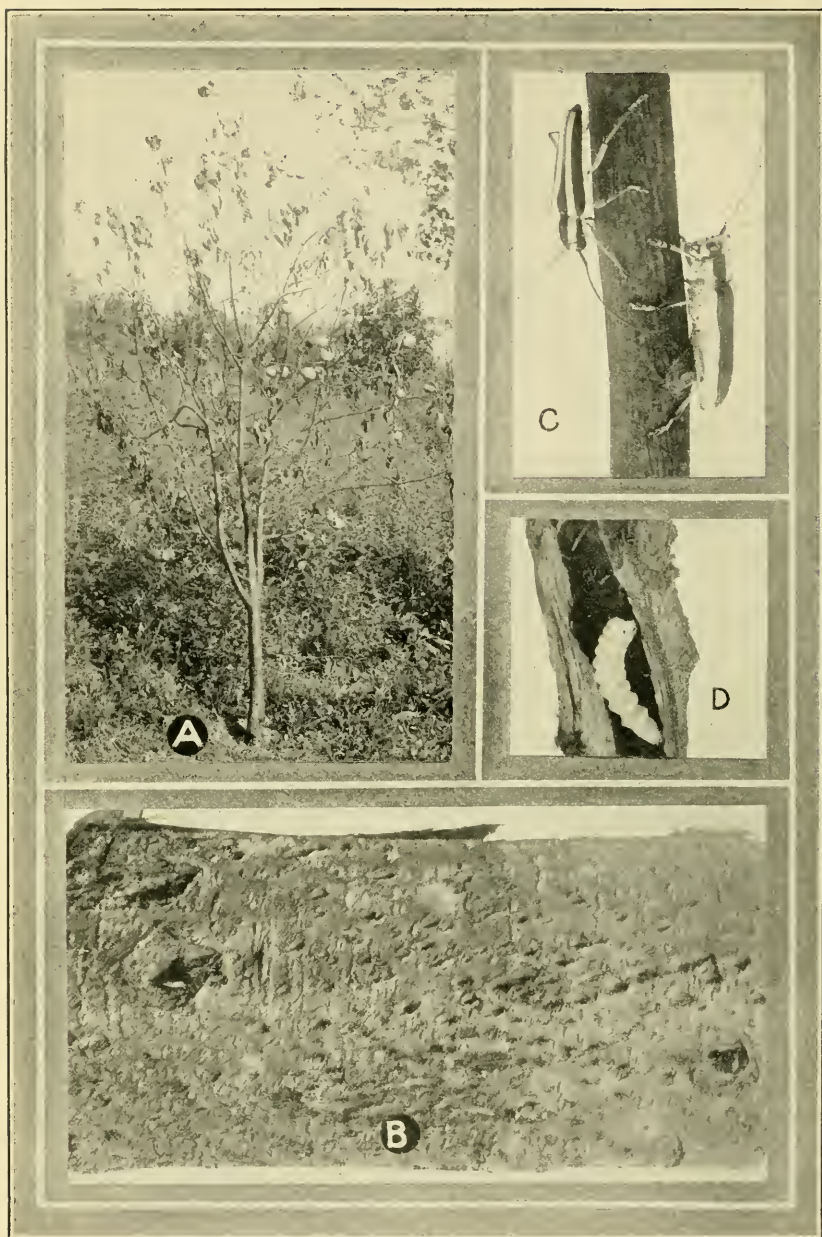
In the late summer and autumn preceding the spring during which pupation is to take place, the larvæ excavate galleries leading up the trunk of the tree a short distance beneath the bark. (Pl. VIII, A, B.) At the upper end of this gallery the pupal chamber is formed by slightly enlarging the circumference of the opening and curving the upper end outward to the inner bark. (Pl. VII, A.) The curved upper end is packed lightly with wood dust and a considerable space in the gallery below the pupal chamber is filled with short, excelsior-like strings of wood torn from the walls of the opening. (Pl. VIII, A.) The space for the pupa is often 2 inches or more in length and both the larvæ and pupæ when occupying it recede or advance when disturbed, evidently a provision for escaping woodpeckers. The pupal quarters usually are practically completed in the autumn but the larvæ add finishing touches in the spring before they pupate. In small trees the exit holes at the upper end of the pupal chambers are usually within from 4 to 8 inches of the ground, but in large trees it is not unusual to find the place of exit at the terminus of a gallery extending upward from the ground to a distance of 18 inches or 2 feet. Just why the pupal quarters should be made higher in large trees than in small trees does not seem to have been determined.

Wintering larvæ begin activities early in the spring and continue to feed until stopped by the cold weather of winter. Probably the annual feeding period in the South is much longer than in the North.



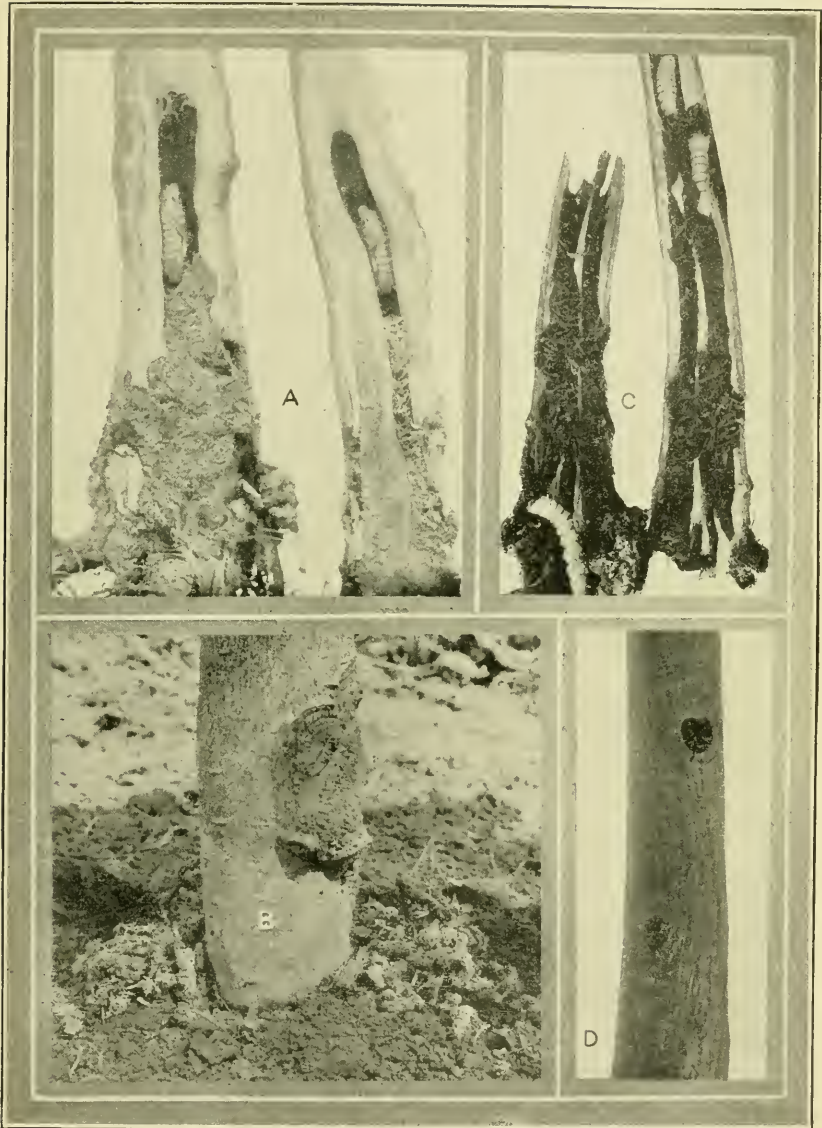
ROUNDHEADED APPLE-TREE BORER.

A, Borer, first summer in tree. Natural size. B, Second summer in tree. Natural size. C, Castings being ejected from tree by borer.



ROUNDHEADED APPLE-TREE BORER.

A, Young apple tree dying from injuries caused by roundheaded apple-tree borers. B, Trunk of young apple tree marked by beak of woodpeckers searching for borers; the larger wounds show where borers have been removed. C, Adult roundheaded apple-tree borers; male above and female below. Slightly enlarged. D, Borer in apple tree; showing cleared space maintained in burrow to allow of free movement of body. Natural size.



ROUNDHEADED APPLE-TREE BORER.

A, Tupæ in natural position in tree. B, Castings of borers at base of young apple tree. C, Borers in young service tree. D, Exit holes of beetles.



ROUNDHEADED APPLE-TREE BORER.

A, Larvæ within pupal chambers in young apple tree. Natural size. B, Cross section of base of trunk of young apple tree, showing galleries made by borers in ascending the trunk to pupate. Natural size. C, Beetle resting by exit hole. Natural size.

FORM OF BURROWS IN PEAR DIFFERS FROM THAT IN APPLE.

It was frequently noted that the borers in pear trees formed differently shaped burrows from those made in apple. In pear the burrow is much more elongate, often being a slender gallery 6 or 8 inches in length and extending around the trunk, sometimes almost or entirely encircling trees several inches in diameter. As the larvæ in pear near maturity they enter the wood and pupate much as in apple.

PERIOD SPENT BY LARVA IN THE TREE.

Ever since the roundheaded apple-tree borer began to attract the attention of entomologists there has been some disagreement as to the number of years spent by the larva in the tree. Practically all writers have agreed that the life cycle requires either two or three years for completion. Most of the well-known textbooks on general entomology, as well as the systematic treatise on this particular species, give three years as the life period. Comstock (4, p. 573) says "It requires nearly three years for this larva to attain its growth." Smith (5, p. 209-210), speaking of the larva, says "In the spring of the third year [it] changes to a beetle." Felt and Joutel (6) give a three-year period in the tree. Saunders (8) says "It is generally conceded that the larva is three years in reaching maturity." Sanderson (12) says "The third spring the larvæ transform to pupæ." Slingerland and Crosby (13) state, "It is generally believed that it requires three years for this apple-borer to complete its life cycle." Lutz (15, p. 359) says, "From egg to adult takes three years." Chittenden (7) gives a three-year life cycle. O'Kane (11) says "The larva requires three years for maturity." Both Smith (10, p. 52-54) and Patch (9) give a three-year larval period. Becker (14) says "*Saperda candida* has a two-year life cycle in the Ozarks," but points out that "There seems to be some indication that occasionally a larva may require three years for its development."

The present investigation has shown that the length of the life cycle averages longer in the North than in the South and also that this period may vary several years in length in a given locality. Table IV shows the years required for 121 insects to reach maturity at French Creek, W. Va.

TABLE IV.—Period of life cycle of the roundheaded apple-tree borer at French Creek, W. Va.

Year beetles issued.	Number years in tree.				
	1	2	3	4	5
1913.....	0	9	0	0	0
1914.....	0	11	2	0	0
1915.....	2	7	1	0	0
1916.....	0	36	10	1	0
1917.....	0	40	2	0	0
Total.....	2	103	15	1	0
Per cent.....	1.7	85.1	12.4	0.8	.....

Table IV shows that out of 121 individuals, 2 issued from the wood as beetles the next year after the eggs were deposited, 103 issued in two years, 15 in three years, and 1 in four years.

Records of the exact number of days elapsing from the deposition of the eggs to the issuing of the beetles were ascertained in a number of instances. These records are shown in Table V.

TABLE V.—*Number of days between deposition of egg and emergence of beetle of roundheaded apple-tree borer at French Creek, W. Va.*

Date egg was deposited.	Date beetles issued from wood.	Number of beetles.		Number of days from egg to beetle.
		Male.	Female.	
June 18, 1913.....	June 1, 1915.....	1	0	713
Do.....	June 14, 1915.....	0	1	726
Do.....	June 8, 1915.....	0	1	720
June 15, 1914.....	May 24, 1916.....	2	0	708
June 18, 1914.....	do.....	2	0	705
June 8, 1914.....	May 25, 1916.....	1	0	716
June 12, 1914.....	do.....	1	0	712
June 18, 1914.....	May 26, 1916.....	1	0	707
June 18, 1913.....	May 27, 1916.....	1	0	1,073
June 18, 1914.....	do.....	0	1	708
June 16, 1914.....	May 28, 1916.....	0	2	711
June 18, 1914.....	do.....	0	1	709
June 11, 1914.....	do.....	0	1	716
June 18, 1913.....	do.....	0	1	1,074
June 11, 1914.....	do.....	1	0	716
June 16, 1914.....	May 29, 1916.....	0	2	712
Total.....		10	10	.....

As is shown in Table V, 1 male spent 1,073 days in undergoing development within the tree and 1 female 1,074 days, a 3-year period for each. All the others reached maturity in 2 years, the 9 males requiring on an average 710 days from egg to adult and the 9 females undergoing the same transformation in an average of 714 days.

Records obtained at Winthrop, Me., show that of 24 individuals, none matured in 2 years, 6 issued as beetles in 3 years from the egg, and 18 required 4 years to develop from eggs to adults. No definite records were obtained for individuals requiring longer than 4 years for development and yet observations were made which indicate a 5-year period in some cases. Observations made at Biltmore, N. C., indicate a 2-year period with most individuals in that locality.

THE PUPA.

The pupa (Pl. VII, A), when first formed, is soft and delicate, the color being similar to that of the larva. Within a few days it turns slightly yellowish, the eyes soon take on a dark color, and later the whole body becomes mottled with brown and blackish markings. The pupa occupies a vertical position in the cell and measures from 18 to 25 mm. in length, the females being much longer and more robust than the males.

PERIOD OF PUPATION.

At French Creek, W. Va., practically all the individuals pass through the pupal stage during the period from April 15 to May 15, although the time of pupation and the duration of the stage depend very much on weather conditions. The earliest pupa was found in the field April 12, 1913, and the latest May 20, 1915, although undoubtedly a few may sometimes occur before and after these dates. In the locality mentioned, the entire pupal period for any one year has not been found to extend over 30 days, the pupal stage for a single individual averaging about 20 days. All transforming individuals were found in the pupa stage at Demorest, Ga., on May 1, 1915; at Winthrop, Me., on June 17, 1916; and at Munising, Mich., on June 20, 1917.

As has been stated, the pupæ are sensitive to temperatures, warm weather accelerating and cold weather retarding the changes. After transforming to the adult stage the beetles usually remain within the pupal chamber from 5 to 10 days, the length of this period, too, depending on weather conditions.

THE ADULT.

The adult (Pl. VI, C; VIII, C) is a handsome, elongate beetle, the males averaging 15 mm. in length and the females 20 mm. The back is cinnamon brown with two broad white stripes extending the full length of the body; the front of the head and underparts are silvery white and the legs and antennæ gray, changing to brownish at the extremities. The antennæ of the males are slightly longer than the body and those of the females slightly shorter than the body.

In escaping from the wood the beetles gnaw round exit holes through the bark at the upper end of the pupal chamber, the holes ranging from 5 to 8 mm. in diameter, the larger ones being those from which females issue (Pl. VII, D).

PERIOD OF ACTIVITY OF BEETLES.

The statements of other investigators regarding the length of time that the beetles of the roundheaded apple-tree borer are on the wing indicate that in some places this period may be of longer duration than in any of the localities where the present writer has made observations. Becker (14), in the summary of his paper, says that in the Ozarks pupation begins in the latter part of March and may continue until the middle of June, and on another page speaks of larvæ that pupated as late as July 11, the inference being that this was under normal conditions. The beetles are said by the same author to be on the wing in the Ozarks from the third week of April

until perhaps as late as the last of August. These statements indicate that in the Ozarks beetles continue to issue from the wood over a period of approximately 100 days. Chittenden (7) states that oviposition has been observed from June to September in a single locality (Lawrence, Kans.) and says that at Albany, N. Y., beetles have been observed in the trees as early as April. Felt and Joutel (6) cite statements of observers giving the months of May, June, July, and August as the time when beetles are abroad.

All the rearings of the present writer indicate that the beetles issue from the wood over a much shorter period than has been found by the writers referred to above. The longest periods covered by the emergence of the beetles were at French Creek, W. Va., where, in 1916, 244 beetles issued from May 20 to June 18, a period of 30 days, and in 1917, when 118 beetles issued from May 25 to June 23, a period of 30 days. No beetles in either year issued before the first dates or after the last dates named. In all the rearings of which the dates of issue were kept, including 772 beetles, the first to issue was at Demorest, Ga., on May 8, and the last at Munising, Mich., on July 23, the interval between these two extreme dates being 78 days.

Table VI presents the data which have been accumulated relative to the time of emergence of beetles in several localities.

TABLE VI.—*Periods during which beetles of the roundheaded apple-tree borer issued from the wood in different localities.*

Year.	Locality.	Number of beetles.	First and last emergence.	Number of days.	Periods over which beetles issued from wood.											
					May.			June.			July.					
					5	10	15	20	25	30	4	9	14	19	24	29
1911..	French Creek, W. Va.	11	May 23-June 1...	10												
1912..	do.....	27	May 14-June 6...	24												
1913..	do.....	95	May 12-June 6...	26												
1914..	do.....	116	May 22-June 8...	18												
1915..	do.....	5	May 25-June 14...	21												
1916..	do.....	244	May 20-June 18...	30												
1917..	do.....	118	May 25-June 23...	30												
1918..	do.....	21	May 18-May 28...	11												
1914..	Weston, W. Va.	35	May 20-June 2...	14												
1914..	Great Cacapon, W. Va.	13	May 20-June 6...	18												
1914..	Elkins, W. Va.	16	May 28-June 5...	9												
1914..	Pickens, W. Va.	24	May 28-June 9...	13												
1914..	Pemberton, N. J.	1	June 21.....	1												
1914..	Winthrop, Me.	23	June 18-June 30...	13												
1915..	Demorest, Ga.	6	May 8-May 14...	7												
1915..	Biltmore, N. C.	2	May 15-May 20...	6												
1916..	Winthrop, Me.	8	June 20-July 3...	14												
1917..	Munising, Mich.	2	July 23-July 25...	3												
Total number beetles..		772														

LENGTH OF LIFE OF INDIVIDUAL BEETLES.

Eight female beetles whose emergence and death were noted in 1911 and 1912 lived, respectively, 27, 31, 37, 41, 41, 44, 46, and 46

days. In 1912 the first beetles issued from the wood on May 14 and eggs were still being deposited on July 1, 48 days after the first beetles appeared. In 1913 beetles were observed on the wing from May 12 to July 19, a period of 68 days. In 1914 a female issued on May 27 and died July 24, living 58 days. In the same year a male and female were alive on August 6, 76 days after the first beetle issued. In 1917 the first beetle left the wood on May 25 and the last beetle of the year died August 10, beetles thus being on the wing for 77 days. In 1918 two females were observed to be alive and active 61 days after leaving the wood. The beetles referred to above were in all cases kept in roomy wire-screen cages over small, growing apple trees, and it is presumed that their life periods extended over the normal term.

FEEDING HABITS OF BEETLES.

The beetles feed to a considerable extent upon both tender and tough bark of twigs and branches and upon leaf stems and leaf ribs, and they frequently chew ragged holes through the tissues of the leaf. (Pl. IX, A, C.) They were observed often working with their mandibles at the castings ejected from trees by larvæ of their own kind and were seen occupied in a similar manner with damp soil; this was probably for the purpose of obtaining water. One female beetle kept alone in a cage over a young apple tree lived for 58 days, and after her death a careful measurement was made of the leaf and bark surface over which she had eaten. The total area eaten was found to be 6.9 square inches. In another instance two male and three female beetles, which had just issued from the pupal quarters, were placed in a roomy cage over a young apple tree that had been sprayed just before with lead arsenate at a strength of 3 pounds of the paste to 50 gallons of water. Two of the beetles died the first day, one died on the second day, one on the third, and the other, a female, died on the ninth day. All apparently succumbed to the poison, as there was no mortality among beetles caged at the same time over unsprayed trees. Death occurred to all the beetles confined over the sprayed tree before any eggs were deposited. It was noted frequently that beetles differed individually in the amount of feeding done immediately following their emergence from the wood, some proceeding to feed at once and others waiting several days. It is probable that the female referred to above, which lived nine days over the sprayed apple tree, did no feeding until a short time before her death.

COPULATION.

Copulation may take place soon after the beetles issue from the pupal chambers or it may be deferred a week or 10 days, the time

of pairing seemingly depending about as much upon the volition of one sex as the other. Newly emerged males occupying cages in company with females have been observed to wait several days before paying any attention to the females. In other cases they have begun courtship on the day following that of their emergence. The females usually repel the males for several days, but will sometimes receive them within an hour after quitting the pupal quarters. Evidently some individuals of both sexes remain in the wood until they are sexually mature, while others issue before the sex instinct has developed.

The act of copulation usually lasts several hours and is repeated at frequent intervals so long as both sexes live and are active. Pairing was several times noted after the participants had been on the wing from 30 to 40 days.

Females confined by themselves were observed to engage in a performance evidently to attract males. They would occupy the upper surface of an exposed leaf and thrust out the ovipositor to its utmost length and then wave it about while it was being gradually drawn in. A few minutes later the ovipositor would be again extended and then drawn in and so the act would continue for an hour or more. Apparently a scent or influence of some kind was being discharged as a sex attraction, but when females so engaged occupied outdoor cages no wild males of the locality were observed to come to the cages.

DAY AND NIGHT ACTIVITIES OF THE BEETLES.

Early writers on this insect described the beetles as being active nocturnally and secreting themselves by day. The beetles were supposed to issue from their pupal cells and deposit their eggs exclusively by night. The reverse of this habit, however, has been found more nearly true. All the beetles issue from their exit holes by day, usually during the forenoon, although a few continue to come forth during the afternoon hours. No evidence was obtained that oviposition ever takes place in the darkness, although male beetles are occasionally on the wing at night. There is a period of activity in the evening just before twilight when both sexes are especially inclined to flight, but as darkness comes on most of the beetles settle among the branches and remain quiet until the light of the morning.

Observations made at night with electric flashlights indicated that the normal habit is to rest in one place through the night, but that occasionally the beetles move about in the darkness.

DO THE BORERS DIFFERENTIATE BETWEEN VARIETIES OF APPLE?

Orchardists often observe what appears to be a preference on the part of the roundheaded apple-tree borer for certain varieties of

apple. Individual trees or blocks of one kind of apple will be attacked year after year much more extensively than those of other varieties. Becker (14) concludes from experiments that the borer does not discriminate between varieties and that the preference which is often indicated is merely a matter of propinquity.

During the present investigations observations were made bearing on this point over a period of five years in the experiment orchard at Elkins, W. Va., As has been stated, this orchard contained only three varieties, namely: 310 King, 341 Grimes, and 341 York Imperial, the block of Grimes occupying a space through the center of the orchard. All the rows of the three varieties abutted impartially at one end against an older and heavily infested orchard. There were no conditions within or surrounding the orchard that would appear more favorable for the attack of one variety than another, except that female beetles in entering the orchard to oviposit might be expected to alight more frequently on the outer trees. During four of the five years over which counts were made, however, the Grimes in the center were much more severely attacked, practically 50 per cent of the 1,639 borers removed from the trees being found in this block. The King trees, although fewer in number, were second in point of attack, and the York Imperial trees suffered least. This ratio of attack, as may be seen from Table VII, was constant for the years 1913, 1914, 1916, and 1917. In 1915, which was the year of lightest infestation, the York Imperials were first in point of attack, the Grimes second, and the Kings third.

TABLE VII.—*Relative extent of infestation by the roundheaded apple-tree borer of three varieties of apple for a period of five years.*

Year.	Variety of apple.					
	King.		Grimes.		York Imperial.	
	Number of borers.	Per cent.	Number of borers.	Per cent.	Number of borers.	Per cent.
1913.....	49	30.3	77	47.5	36	22.2
1914.....	80	33.5	110	46.0	49	20.5
1915.....	8	8.3	43	44.8	45	46.9
1916.....	223	35.4	283	44.8	125	19.8
1917.....	121	23.7	303	59.3	87	17.0
Total.....	481	29.3	816	49.8	342	20.9

It is entirely possible that the results which are shown in Table VII are accidental, and yet it must be confessed that, aside from varietal preference on the part of female beetles while ovipositing, there is no apparent way of accounting for the almost constant maximum attack of Grimes and minimum attack of York Imperial.

DISTANCE OF FLIGHT OF FEMALE BEETLES DURING OVIPOSITION.

The probability that the female beetle during her egg-laying activities does not normally wander far in search of host trees has been suggested by the fact that the trees containing the larvæ are usually found in somewhat restricted groups. This grouping of the borers occurs not only in orchards but in the woods as well, and indicates that where host trees grow near together the adult females during oviposition are not inclined to fly far from the trees in which they develop. In an effort to obtain data bearing on this point several experiments were carried out in West Virginia, which are described below.

THE DARNALL ORCHARD.

This orchard contained 537 apple trees ranging in age from 4 to about 20 years. In the summer of 1914 it was found to be badly infested with roundheaded apple-tree borers, and the trees were gone over carefully after the eggs of the current season had hatched, all the borers being removed and counted. The trees contained 141 borers, 106 of which had only recently hatched. The orchard was surrounded by pasture lands and woods in which grew an abundance of seedling apple, wild crab apple, hawthorn, and service trees. Within a strip 600 feet in width surrounding the orchard these outlying trees were also examined and all the borers removed and counted, the number of borers found being 95. This operation was repeated annually for a period of 4 years, it being obvious that if borers were not allowed to breed within the area all the young borers found within the orchard after the first year would necessarily have hatched from eggs deposited by female beetles which had flown into the orchard from outside the 600-foot strip.

In the second year of the experiment (1915) an examination of the orchard trees showed that female beetles had crossed the 600-foot strip and deposited 56 eggs. The third year (1916) only 1 egg was deposited in the orchard. The fourth year (1917) beetles flew across the boundary strip and deposited 44 eggs in the orchard trees. While this was a considerable reduction from the number of eggs deposited annually in the orchard before the experiment began, still it showed a rather general tendency on the part of the female beetles to fly at least 600 feet in searching for trees in which to oviposit.

In figure 2 are given plats of the Darnall orchard showing the location of infested trees and the number of borers found at each of the four annual examinations.

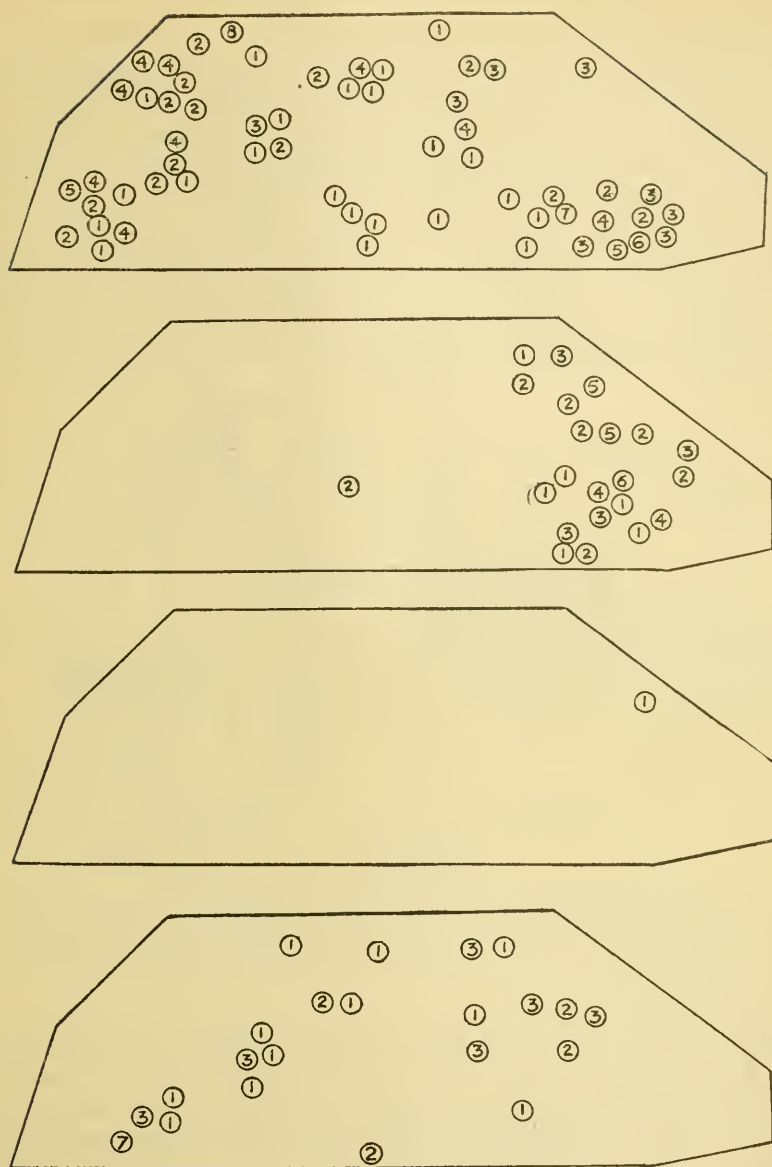


FIG. 2.—*Saperda candida*. Plats of Darnall orchard illustrating distance of flight of female beetles during oviposition. Circles represent location of infested trees and the figures within them show number of borers found. No beetles were allowed to develop within 600 feet of the orchard. Plat 1: Position of infested trees and number of borers found at first examination (1914). Trees contained 106 young borers and 35 from eggs of previous seasons. Plat 2: Position of 56 borers developing from eggs deposited in 1915 by beetles that had flown into the orchard from outside the 600-foot strip. Plat 3: Position of one egg deposited by female which entered the orchard from outside the 600-foot strip in 1916. Plat 4: Position of 44 eggs deposited by beetles which entered the orchard from outside the 600-foot strip in 1917.

THE PAGE ORCHARD.

The Page orchard, like the Darnall orchard, was found in 1914 to be heavily infested with roundheaded apple-tree borers. The trees within the orchard and within a strip 300 feet in width surrounding the orchard were cleaned of borers. The orchard contained 464 trees from which were removed 290 borers, 254 of which were from eggs of the current season. This orchard was surrounded entirely by pasture lands over which grew scattering seedling apple, crab apple, and hawthorn trees in which many borers were developing. The second annual examination, which was made in August, 1915, showed that 55 eggs had been laid in the orchard trees. One

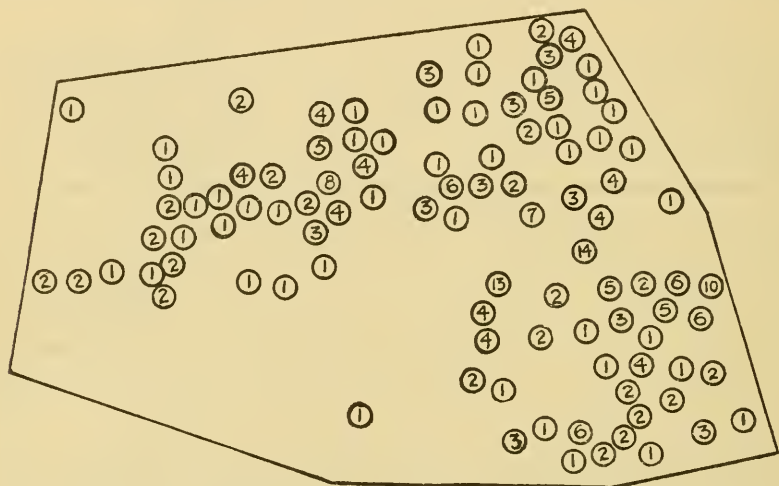


FIG. 3, A.—*Saperda candida*. Plat of Page orchard illustrating distance of flight of female beetles during oviposition. Circles represent locations of infested trees and the figures within show number of borers found. Orchard surrounded by 300-foot strip cleaned of borers. Plat 1: Infested trees and number of borers found at first examination (1914). Orchard contained 290 borers, 254 of which developed from eggs of the current year.

borer had been overlooked in the orchard during the examination of the previous year and this had developed into an adult female, as was apparent from the size of the exit hole, and near to the tree from which it issued two trees were found containing, respectively, 4 and 9 young borers. In another part of the orchard a group of 7 trees contained 42 young borers. This group of infested trees was near the outer border of the orchard, and 275 feet distant another fresh female exit hole was found in a seedling apple growing in the pasture field, the author of which had been overlooked the previous year. It seemed probable that this beetle had flown to the orchard and that the two females overlooked the previous year were responsible for all the eggs which were deposited within the orchard in 1915.

The third year (1916) 38 eggs were distributed among 10 of the orchard trees, all evidently having been laid by females that flew into the orchard over the 300-foot strip.

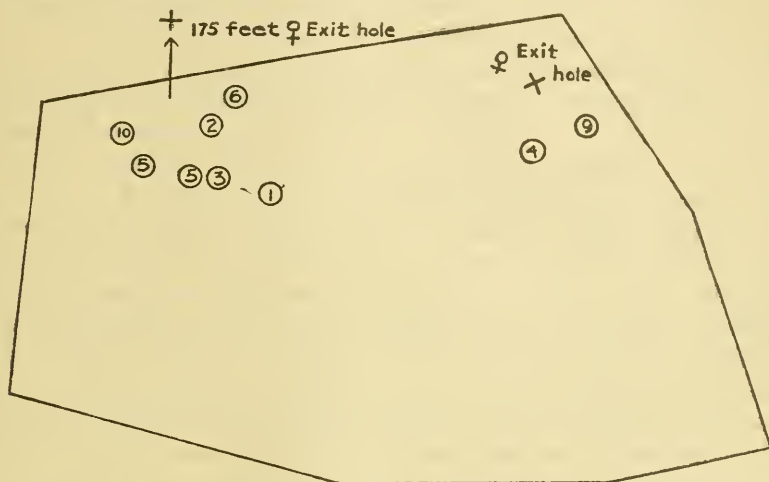


FIG. 3, B.—*Saperda candida*. Plat of Page orchard illustrating distance of flight of female beetles during oviposition. Circles represent locations of infested trees and the figures within show number of borers found. Orchard surrounded by 300-foot strip cleaned of borers. Plat 2: Number of borers found in second examination (1915). Fifty-five borers present from eggs of current season. Crosses indicate where two female beetles issued that had been overlooked as borers during the previous annual examination.



FIG. 3, C.—*Saperda candida*. Plat of Page orchard illustrating distance of flight of female beetles during oviposition. Circles represent locations of infested trees and the figures within show number of borers found. Orchard surrounded by 300-foot strip cleaned of borers. Plat 3: Number of borers found at third examination (1916). Thirty-eight borers were present, all having evidently hatched from eggs deposited by females which had entered the orchard across the 300-foot strip.

The Page orchard and the strip surrounding it were kept clean of borers for three consecutive years. The plats above (fig. 3) show the condition of the orchard as to infestation at each examination.

It will be seen that the results of the experiment in the Page orchard were fully as good as those obtained in the Darnall orchard, although the cleaned strip surrounding the trees was only half as wide. This may be accounted for by the fact that the breeding conditions for borers surrounding the Page orchard were much less favorable than those surrounding the Darnall orchard and fewer beetles were developing in the locality.

The results of the experiments described and illustrated above for determining the distance which beetles will fly during the period of oviposition are suggestive although not entirely conclusive. It will be noted that every year in both orchards after the experiments began there is evidence that female beetles crossed the surrounding strip of borer-cleaned territory to oviposit in the orchard. In all cases, however, there was a decided improvement in the borer conditions within the orchards after the development of beetles within cases, however, there was a decided improvement in the borer conditions of infestation on the number of young borers found in the orchards at the first examinations, we have thereafter percentages of borer reduction which may be tabulated as follows:

TABLE VIII.—*Improvement in roundheaded apple-tree borer conditions derived from preventing the development of adults within and adjacent to the orchards.*

Name of orchard.	Year.	Width of cleaned-up strip surrounding.	Number of borers found.	Percentage of gain.
		<i>Feet.</i>		
Darnall.....	1914.....	600	106	.....
Do.....	1915.....	600	56	47.1
Do.....	1916.....	600	1	99.1
Do.....	1917.....	600	44	58.5
Page.....	1914.....	300	254	.....
Do.....	1915.....	300	55	78.3
Do.....	1916.....	300	38	85.0
Total average gain in both orchards.....				73.6

As is shown in Table VIII, the average improvement in borer conditions in both orchards derived from the stopping of the development of adults in the immediate localities was 73.6 per cent.

FURTHER TEST OF THE FLIGHT OF FEMALE BEETLES.

One of the orchards used in experiments dealing with the round-headed apple-tree borer contained 992 young apple trees planted in 31 rows of 32 trees each. Row 1 extended parallel with the outer row of an older orchard that was heavily infested with borers, the experiment orchard being surrounded on other sides by grown-up

fields in which scattering seedling apple and service trees grew. Undoubtedly beetles developed within these outstanding trees and flew into the experiment orchard to oviposit, providing thereby for an unknown number of borers, which can not be eliminated from the numerical results of the experiment described below. The rather heavy infestation, shown below, of rows 1 to 5 can be accounted for only on the ground of an overflow of adult females from the adjacent older orchard.

In the experiment orchard during three separate years newly emerged beetles of both sexes were distributed among the trees of row 16, which extended through the center of the orchard. The beetles used were removed from rearing cages and placed on the trunks of the trees, care being exercised to disturb or excite them as little as possible. The sexes of the beetles were about equally divided as to numbers. After a sufficient time had elapsed for all the eggs to hatch which were deposited by the liberated females, the orchard was gone over and the number of borers found in each row recorded. The results showed with some degree of accuracy the extent to which the females in ovipositing wandered away from the trees upon which they were liberated. In 1914, 25 females were liberated on row 16; in 1916, 87 females were liberated on the same row; and in 1917, 12 were distributed in like manner. In the year 1915, nine females were liberated on row 29. In all cases males accompanied the females.

Table IX shows the distribution by rows of the borers found in the orchard each season following the liberation of the female beetles on row 16.

TABLE IX.—*Distribution of roundheaded apple-tree borers hatching principally from eggs deposited by female beetles liberated on the central row of the orchard. Orchard contained 31 rows of 32 trees each and beetles were placed on row 16.*

No. of row.	Number borers found.			Total.	No. of row.	Number borers found.			Total.
	1914	1916	1917			1914	1916	1917	
1	1	20	25	46	17	18	23	28	69
2	3	23	13	39	18	7	25	19	51
3	5	23	23	51	19	9	14	21	44
4	2	23	23	47	20	5	29	21	55
5	1	22	2	25	21	7	19	24	50
6	2	14	9	25	22	12	13	22	47
7	9	21	4	34	23	10	12	12	34
8	3	28	7	38	24	9	14	23	46
9	22	24	7	53	25	9	11	18	38
10	9	21	7	37	26	8	14	3	25
11	3	12	8	23	27	3	26	8	37
12	14	19	19	52	28	7	21	6	34
13	12	31	9	52	29	1	18	18	37
14	10	10	18	38	30	6	12	14	32
15	7	39	26	63	31	1	31	18	50
16	24	29	50	103					

Total number borers..... 1,375

Table IX shows that in row 16, where the adult females were liberated, the total number of borers for the three years was greater than in any other row of the orchard. It shows also that a few rows on each side of row 16 contained considerably more than the average number of borers for the other rows of the orchard.

In 1915 nine female and several male beetles were liberated on row 29. A later examination showed that this had resulted in the greatest number of borers occurring in row 29, the central rows of the orchard having this year the fewest borers.

The results shown in Table IX and the distribution of the borers found in 1915, when the females were placed on row 29, are set forth graphically in figure 4.

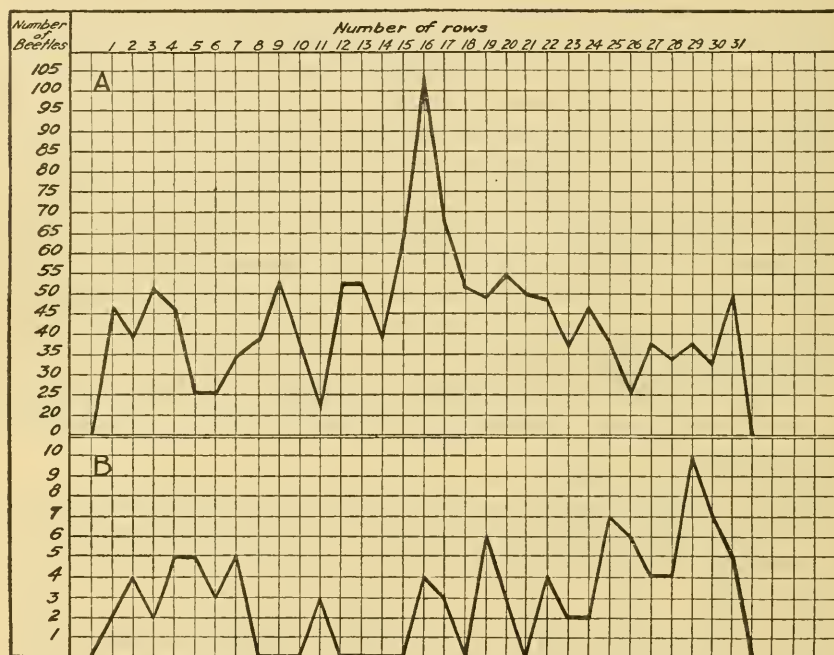


FIG. 4.—*Saperda candida*. Diagram showing tendency of female beetle to refrain from long flights during oviposition. A, Number and distribution of borers found in orchard after liberating 124 female beetles during three separate years on row 16. B, Number and distribution of borers found after liberating 9 females on row 29.

All the foregoing data on the flight of the female point to a constant tendency on her part to deposit eggs near the place of her development. They also afford good evidence that the female beetle is capable of flights of considerable distance when impelled by any special desire.

In one case when a female was liberated in the manner described above, she immediately took wing and arose to a height of 30 or 40 feet and then disappeared in the direction of a tract of woods about

500 yards distant. That such flights are unusual, however, is indicated by all the evidence that could be gotten.

FEMALES LESS PRECOCIOUS THAN MALES.

The females are not only less active in flight and more sluggish generally than the males but are regularly two or three days behind the males in issuing from their pupal quarters in the wood. This constant tendency on the part of females to be slower than the males in emergence is illustrated by figure 5.

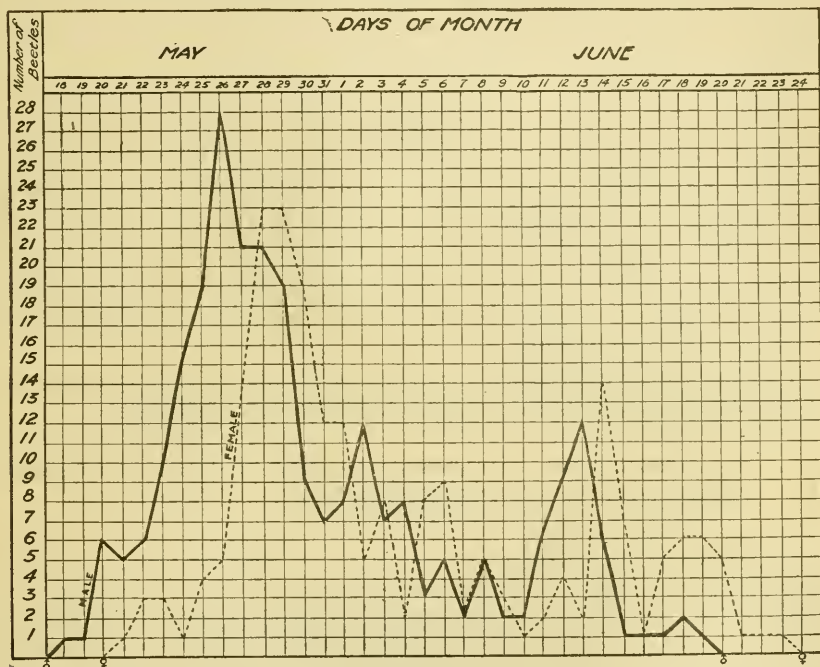


FIG. 5.—*Saperda candida*. Diagram illustrating the relative time of emergence of male and female beetles. Based on 261 males and 206 females that issued under natural conditions at French Creek, W. Va., in 1914, 1915, 1917, and 1918.

SEASONAL PHENOMENA OF THE HOST TREES AS AN INDEX TO THE TIME OF DEVELOPMENTAL CHANGES OF THE INSECT.

Since this borer occurs in North America from southern South Carolina and Texas northward into Canada the calendar dates of its metamorphic changes in different latitudes must vary considerably. There must also be a considerable yearly variation in the dates of these changes in any given locality, due to the early or late advent of spring.

In the rearing work with this species it was found that between Demorest, Ga., and Winthrop, Me., there was a difference in time of

emergence of the first beetles of about 40 days. On Grand Island, in northern Michigan, the first beetles appeared 75 days after the date of the first appearance in Georgia. In the several years during which beetles were reared at French Creek, W. Va., there was a variation of 13 days in the dates of the first adults to issue. Calendar dates are therefore of little value in expressing the time when a given metamorphic change of the insect takes place. It was found, however, that the time of certain transformations and activities of the borer may be anticipated or determined very conveniently by observing the definite annual steps in the development of foliage, flowers, and fruit of the apple and other trees upon which the insect lives.

The first blossoms to appear on apple follow closely the first activities of the borers in the spring and it is just in advance of apple blossoming time that the first fresh castings thrown from trees by borers may be looked for. Also, the blooming time of apple corresponds quite definitely with the pupal period of the insect. The oviposition time of the beetles begins with and extends somewhat beyond the ripening season of the fruit of the service tree. These rules hold good in a general way for all latitudes and altitudes and for early and late springs.

The following field notes arranged in Table X indicate the coincidence of these events in a number of different localities:

TABLE X.—*Indicating the correspondence in time of certain developmental changes in the roundheaded apple-tree borer and its host trees.*

Locality.	Date.	Field note.
Frenchton, W. Va.....	Apr. 27, 1914	Blossoms of York Imperial and Maiden Blush one-half open. One pupa of <i>S. candida</i> found.
Weston, W. Va.....	Apr. 28, 1914	Apple trees in full bloom. More than half the transforming borers have pupated.
Great Cacapon, W. Va.....	May 5, 1914	Apples a little past full bloom. About 25 fresh pupæ of <i>S. candida</i> collected.
Pickens, W. Va.....	May 20, 1914	Three-fourths the apple petals off. Maturing borers all in pupal stage.
Winthrop, Me.....	June 22, 1914	Apple blossoms have been off 2 weeks or more. Pupæ of <i>S. candida</i> still present. A few have issued.
Gadsden, Ala.....	Apr. 29, 1915	Apple petals have been off 6 days. One pupa of <i>S. candida</i> found.
Demorest, Ga.....	May 1, 1915	Apple trees just past full bloom. All maturing <i>S. candida</i> in pupal stage.
Biltmore, N. C.....	May 4, 1915	Do.
French Creek, W. Va.....	Apr. 20, 1916	First apple blossoms opened to-day. Half the transforming borers have pupated.
Do.....	Apr. 25, 1917	First apple blossoms opened Apr. 22. All maturing borers have pupated Apr. 25.
Do.....	Apr. 27, 1917	Borers in apple threw out first castings a few days in advance of first apple blossoms.
Munising, Mich.....	June 20, 1917	First apple blossoms opening. About a dozen fresh pupæ of <i>S. candida</i> found.
French Creek, W. Va.....	Mar. 26, 1918	Apple buds showing first pink. Fresh castings first appearing from 1-year-old borers.
Do.....	May 15, 1918	Last petals falling from apple. Transforming borers all pupæ except one male which has changed to beetle.
Do.....	June 13, 1914	First fruit of service ripened May 29. First eggs of <i>S. candida</i> June 4. Fruit of service overripe June 13. Egg laying of <i>S. candida</i> at height June 13.

NATURAL ENEMIES.

Possibly no other economic insect of equal importance has had so few natural enemies recorded definitely and specifically as has the roundheaded apple-tree borer. In all the literature upon this borer, there seems to be only one original reference to such an enemy, this being the single instance of the hymenopterous parasite *Cenocoelius populator* Say, reared about 30 years ago by Riley and Howard (3, p. 59) from borers of this species received from Indiana. Felt and Joutel (6) state that an undetermined carabid larva was found preying on the borers by Walsh and Riley, and practically all observers have noted that woodpeckers are an important enemy, although in no case is the specific identity of the bird or birds established, so far as the records show.

In rearing and handling many thousands of the borers in various localities the writer has never found any evidence of hymenopterous parasites. In two instances undetermined carabid larvæ were found devouring young borers in West Virginia and another half-grown borer was found that had been killed by a hairworm, sections of the worm being found in the burrow entwined around and within the dead and shriveled body of its host. A large spider was seen to pounce upon and bite in the back a female beetle that had just issued from her exit hole in a tree. In an effort to rescue the beetle the spider was crushed beyond recognition. The beetle died a few hours later from the wound.

WOODPECKERS.

While the control effect of parasites and predacious insects on this borer is negligible, woodpeckers play an important part in holding it in check. Wherever the writer has collected specimens or made observations in borer-infested localities the work of these birds has always been in evidence. Soon after the borers hatch the woodpeckers begin to find them beneath the thin covering of bark and thereafter the birds drill for them as long as they are in the tree. In several orchards where counts were made from 50 to 75 per cent of the borers had been destroyed in this way.

During October, 1915, 24 young borers were collected and planted in furrows gouged out of the wood beneath loosened tongues of bark on the trunk of an apple tree. A week later, when the tree was revisited for the purpose of putting a wire screen around the trunk to protect the borers from birds, woodpeckers had punctured every tongue of bark and removed the borers from beneath. Not one had escaped. In May of the same year, while pupæ were being collected from an orchard, a total of 11 pupal cells were found and from every one the occupant had been removed by woodpeckers. In another case

21 pupal cells were found, 19 of which had been opened by woodpeckers and the insects removed.

During the winter of 1915 the writer had standing near his office window a young apple tree in which there were known to be three borers ready to pupate the following spring. The borers had been protected previously by a wire screen but now the screen was removed. On December 21 a male downy woodpecker, *Dryobates pubescens medianus* (Swains), was observed to alight on the base of the trunk and move about alternately tapping the bark and assuming a listening attitude. Presently, with a few vigorous strokes, it drilled through the bark at the point where the future exit hole of a beetle was to have been and at once drew forth and swallowed a large borer. (Pl. V, B.) A minute or two later it located a second borer, disposed of it in the same way, and then flew away without further search. Again, in January, 1916, the trunk of a young apple tree known to contain full grown borers was planted in a natural position near the same office window. A few days later a pair of downy woodpeckers came to the tree and after a brief search the female was seen to remove and swallow a borer. A little later the male found and removed another. The birds would move about over the trunk tapping lightly with their beaks until the quarters of a borer were located. Then with a few sharp strokes they would penetrate to the burrow and remove and devour the insect. The female bird located and removed her specimen through the partly prepared exit hole in less than a minute, but the male drilled industriously for his nearly five minutes, making during the time several openings into the wood which extended in a line over the burrow made by the borer in ascending the trunk to prepare its pupal chamber.

Other observations were made which indicate that the hairy woodpecker, *Dryobates villosus villosus* (L.), also destroys the borers, but this bird was not seen in the act of removing the insects from the tree.

METHODS OF CONTROL.

Ever since the roundheaded apple-tree borer was first recognized as a serious orchard pest, two principal ways of combating it have been advocated: First, the worming process, in which the borers are removed from their feeding places in the tree by the use of a knife and other tools (Pl. IX, B); and, second, the covering of that portion of the trunk of the tree where the eggs are most frequently laid with some protective wash, paint, or mechanical device which will act as a barrier against the female beetles during oviposition. Both of these methods are commonly practiced in orchards and have been the lines of most frequent and extensive experimentation by investigators of borer injury and control. In the present studies, modifications of

these two methods have received special consideration. Tests were made of the effects of penetrating liquids of an irritating or poisonous nature when applied to the bark beneath which borers were feeding, of gaseous and poisonous liquids injected into the burrows, of sticky substances applied to the trunks of trees for the purpose of entangling the adults during their egg-laying activities, and of killing the adults by the use of poisonous sprays. Studies were made also of the distance which female beetles may fly in search of trees in which to oviposit, with the idea of determining the possibility of preventing the infestation of orchards by destroying near-by breeding places. These various tests are described in detail below under their various headings.

WORMING.

The labor of removing borers from trees with a knife and wire is not relished by the majority of orchardists, and yet the difficulties and expense of the task are less than in many other necessary operations in dealing with insect and fungous enemies. Two men, on an average, with an insignificant expenditure for tools and material, should worm 500 trees in a day and obtain as high a percentage of control as ordinarily results from a spraying operation against the codling moth or San Jose scale. Not only does a thorough worming of an orchard rid the trees of the borers present at the particular time but it insures a decreased number of borers for the following one or two years. As is shown on pages 20 to 24, by preventing adult borers from developing within and adjacent to an orchard a reduction may result of about 75 per cent in the number of borers that will attack the orchard the ensuing year.

The process of worming is well understood; the best tools for the purpose being a garden trowel for removing the earth and litter about the trees, a pocketknife with a long, sharp blade, a narrow chisel for securing borers that have penetrated deep into the wood, and a piece of slender wire (Pl. IX, B) about a foot in length with a sharp hook bent at one end and a tag or bit of conspicuous cloth attached to the other end to safeguard the wire against loss. These tools may be carried conveniently in a small fruit basket. The writer found that worming can best be done by two men working together on opposite sides of the tree. With a little practice, one becomes quite adept at locating burrows and hooking the borers from their retreats. After a little skill has been acquired the chisel will have to be used only on rare occasions when deep burrows in the wood are found to be so crooked that the wire on being inserted will not follow the openings.

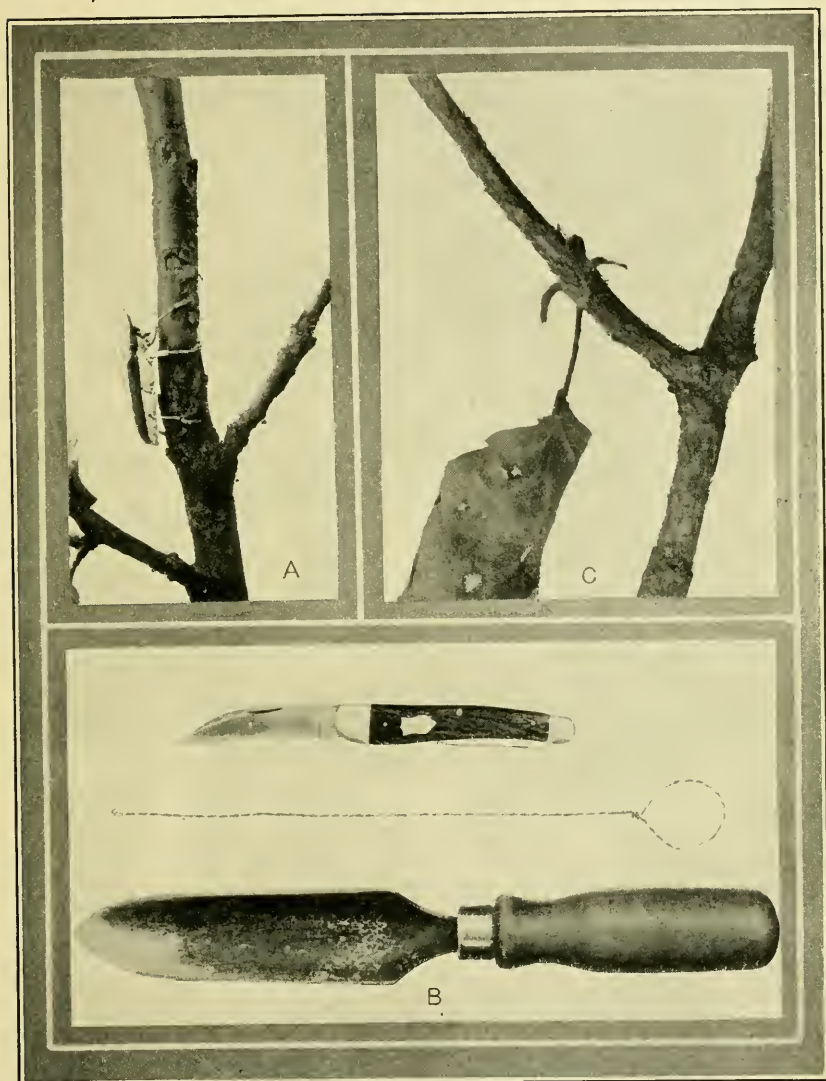
Worming should be done as soon as possible after the last eggs of the year have hatched, as young larvæ usually feed rapidly and

often injure small trees severely the first season. The proper time for the autumn worming varies two months or more between the southern and northern limits of the insect's range, and no definite date can be given which applies to all localities. A safe rule is to have the worming job over before the time arrives for gathering the first winter apples. The borers continue to injure the trees during warm weather of late autumn and early winter, often ejecting their castings in the latitude of West Virginia as late as December 1. It is best to prevent all possible injury by getting the worming done previous to the press of apple-picking time. Trees should have a second worming in the spring soon after the blossoming time of the apple, as it is practically impossible to secure all the borers at one examination. Borers are usually easy to locate by their fresh castings soon after apple trees bloom. (Pl. VII, B.)

At present no cheaper or more effective method of combating this borer is known than that of worming. In order to get best results, however, the work in the orchard must be done thoroughly, and near-by breeding places, such as scattering growths or clumps of apple, wild crab, mountain ash, hawthorn, and service trees eliminated either by destroying the trees or by worming. Many orchards are wormed thoroughly every year, and just as regularly beetles developing in adjacent trees fly over the fence and provide annually for other generations of borers. For most effective control, therefore, the worming operation should include not only the orchard but the trees of the locality immediately surrounding the orchard in which borers breed, and the trees should be examined twice annually, first in late summer after the egg-laying season is past and again in the spring after the blossoming time of the apple.

WASHES, PAINTS, AND MECHANICAL PROTECTORS.

Various materials and devices have in the past been applied to the trunks of trees, either to prevent the female beetles from getting at the bark to oviposit or to kill the borers while feeding in the bark or wood. For preventing oviposition protective coverings, either of a liquid or mechanical nature, have been tested, and, for killing the borers, penetrating poisonous or irritating liquids have been recommended. In the present investigations about 50 kinds of washes, paints, and mechanical devices were tested as to their effectiveness in preventing egg laying and for killing the borers within the trees. Many of these materials were homemade or homemixed and many others were commercial products purchased either from the manufacturers or on the market. Nothing in the way of trunk protectors was tested, however, that gave satisfactory results in all cases. Some applications afforded full or a considerable measure of protection against



ROUNDHEADED APPLE-TREE BORER.

A, Beetle gnawing bark from apple branch. B, Tools for use in worming trees. C, Apple branch denuded of bark by beetles.

ovipositing females but could not be applied safely to trees on account of the injury to bark or wood. All degrees of tree injury were obtained, consisting of a slight yellowing and dropping of the leaves, checking of growth, roughing and cracking of the bark, rank growth of water sprouts, and killing outright. Some forms of protectors caused the beetles to lay their eggs higher up the trunk than is the custom, the only apparent advantage in their use being that the resultant borers were easier to get at in the worming process. Some other materials, such as white-lead paint, gave excellent results in certain cases, and in others where the same material was used in the same way, the female beetles bit through the coat of paint and deposited eggs freely in the bark beneath. In practically all cases, the time and expense required to make and apply protectors of this entire class are greater than those called for in the worming operations, and the results in controlling the borers are less satisfactory.

PROTECTORS USED AGAINST OVIPOSITING BEETLES.

Since a large proportion of the eggs of this borer are normally deposited within the bark of a limited space just above the ground, it would seem a simple matter to cover or protect in some way that part of the trunk so as to force ovipositing females to go elsewhere to lay their eggs. A considerable number of such protectors were tried over a series of years in a young apple orchard of a thousand trees planted for experiment purposes at Elkins, W. Va. The orchard was set in rows of 31 trees each, and most of the materials were applied to trees of a single row, leaving the trees of an adjoining row untreated to be used as checks. In every case where paint-like materials were used for more than one year fresh applications were made annually. This was necessary for the reason that the growth of the trees caused all substances to crack and expose areas of the bark. The results of several of these tests are given below in Table XI.

Table XI shows that a considerable measure of control was obtained by most of the protectors used. None, however, was entirely satisfactory in every respect.

In addition to the protecting materials mentioned in Table XI, a large number of others were tested. These included proprietary and commercial products in the form of paints, soaps, tar products, whitewash combinations, viscous substances, nicotine washes, and paper and metal contrivances, all intended to keep the female beetles away from the bark either by offering mechanical barriers or by making approach to the bark so difficult or disagreeable that they would go elsewhere to oviposit. None of these was without objectionable qualities, either from the high cost, injury to trees, or lack of effectiveness in keeping out the borers.

TABLE XI.—*Effects of various protectors applied to the trunks of apple trees to prevent beetles of the roundheaded apple-tree borer from ovipositing in the bark.*

Kind of protector used.	Num-ber of trees treated.	Num-ber of years used.	Number of borers found each year in treated trees.					Total num-ber of borers in treated trees.	Number of borers found each year in check trees.					Total num-ber of borers in check trees.	Per cent borers were re-duced by treat-ment.	Remarks.
			1913	1914	1915	1916	1917		1913	1914	1915	1916	1917			
White lead and boiled linseed oil.....	31	5	0	4	2	4	2	12	4	7	25	13	10	59	79.7	No injury to trees.
White lead and raw linseed oil.....	31	5	5	6	3	12	11	37	12	23	5	29	28	97	61.9	Do.
Commercial white-lead paint.....	31	4	0	1	0	9	8	18	0	12	2	48	40	102	82.4	Do.
Axle grease.....	25	2	0	0	0	0	0	0	9	4	0	0	0	13	100.0	Trees killed.
Gas tar.....	31	3	8	1	0	0	0	9	9	14	25	0	0	48	81.3	Trees severely injured.
Soft potash soap.....	31	3	0	9	0	8	0	17	9	10	2	17	0	29	41.4	No injury to trees.
Asphaltum.....	31	4	2	5	0	11	0	18	4	7	25	13	0	49	63.3	Do
Whitewash.....	31	1	12	0	0	0	0	12	0	13	0	0	0	13	7	Do.
Whitewash and glue.....	31	2	0	0	20	0	0	20	0	0	8	24	0	32	37.5	Do.
Lime-sulphur wash.....	31	5	5	4	0	16	9	34	8	12	2	48	40	110	69.0	Do.
Tarred-paper wrappers.....	11	2	0	0	0	0	0	0	1	1	0	0	0	2	100.0	Trees killed.
Burlap wrappers.....	31	1	9	0	0	0	0	9	9	0	0	0	0	9	0	Little injury. Eggs laid above wrappers.
Wire-screen wrappers.....	31	1	6	0	0	0	0	6	16	0	0	0	0	16	62.5	Little injury to trees.
Grass and brush around trunk.....	25	1	8	0	0	0	8	8	0	0	0	0	5	5	37.5	Grass and weeds kept moved around check trees.
Ground around trunk smooth.....	31	1	0	0	0	0	7	7	0	0	0	0	6	6	14.3	—

A series of tests were made with applications of casein and glue in varying combinations with gypsum, paris white, china clay, syllex, barytes, zinc white, and other pigments, but none of the materials had sufficient lasting qualities to recommend them.

WHITE-LEAD PAINT.

Nothing in the foregoing line of protectors gave better results from every standpoint than white-lead paint. As is shown in Table XI, three forms of this paint were used, one in which the lead was mixed with boiled linseed oil, one with raw linseed oil, and one ready-mixed paint purchased on the market. The first two mixtures were applied annually to 31 trees each for six years and the last to 31 trees for four years. At the end of the periods none of the trees showed any injury, growth being normal and comparable in every way with that of check trees growing in adjacent rows. The total number of borers found during the entire periods of treatment in the trees painted with white lead was 67, the number found in an equal number of check trees during the same period being 258. This shows for the paint a control efficiency of 74.3 per cent.

In one test of paints a large wire-screen cage was built over a clump of 15 4-year-old apple trees in a neglected nursery row. Three of the average-size trees were painted at the base with white-lead paint, 3 with a proprietary tree paint, and 9 were left untreated. As soon as the paint was dry, 7 male and 7 female beetles that had just issued from apple wood were confined in the cage. At the end of the season an examination showed that 193 eggs had been laid by the 7 females, every egg being in the 9 untreated trees, the paints showing 100 per cent efficiency in control. The same season a female beetle that was ready to oviposit was removed from a cage and placed on the trunk of an apple tree in the orchard that had been treated with white-lead paint in the same way as those in the cage. When liberated the female at once crawled up the trunk to a point above the paint, made a slit in the bark, and deposited an egg. She then moved down near to the ground, and, with no apparent difficulty, bit a hole through the paint, made the oviposition slit in the usual way, and placed an egg in the opening. These and other observations showed that the beetles can very easily oviposit through the paint but prefer to place their eggs in the natural bark.

It was very noticeable that some of the borers hatching from eggs deposited beneath a coat of white-lead paint were at first affected deleteriously by the oil which penetrated into the bark. They were slow in getting a start, fed but little, and, in a few cases observed, died within a few weeks after hatching without having made any perceptible growth. Others that were able to burrow deeper into the tissues, beyond the effect of the oil, grew and developed normally.

Considering the ease with which white-lead paint can be procured, the nominal cost of applying it, its noninjurious effect upon the tree, its frequent deterring effect upon the young borers, and its degree of efficiency in preventing oviposition in the tree, the observations of the writer indicate that where protectors of this general class are desired this paint is preferable to other materials. Such paints or protectors as are described above should be applied to the lower portions of the trunks of trees soon after the blossoming time of the apple.

APPLICATIONS FOR KILLING BORERS IN THE TREE.

Various attempts were made to kill the borers, especially while they were young and near the surface, by applying penetrating poisonous and irritating liquids to the bark. With the same object in view, gaseous liquids were also injected into the burrows of larvæ in all stages of development. The details of several of these treatments follow.

NICOTINE SULPHATE.

In September, 1918, 26 apple trees infested with roundheaded apple-tree borers were located, all the burrows opened with a knife, and about a teaspoonful of 40 per cent nicotine sulphate, at a strength of 1 part to 20 parts of water, injected into the opening with a medicine dropper. In all, 67 burrows were treated. An examination made a month later showed that 26 small borers had been killed and 41 of all sizes were alive and active. It was apparent that where the liquid had come into direct contact with the borer death resulted, but where the liquid did not reach the insect no effect was discernible. In another test 29 burrows were treated in a similar manner with 40 per cent nicotine sulphate undiluted. A later examination showed that 21 borers were killed and 8 were uninjured. Of those killed all except one was of small size and all had apparently been doused with the liquid at the time of the application.

In making the opening into the burrow through which to inject the liquid, care had always to be exercised to avoid killing the smaller borers with the knife. The results of the tests showed that this treatment is impracticable. Further data regarding the effect of nicotine sulphate upon the borers when applied to the bark of infested trees are given in Table XII (p. 38).

CARBON DISULPHID.

Tests were made of the practicability of using a veterinary hypodermic syringe and needle for injecting carbon disulphid through the bark into the burrows of the borers. Considerable difficulty was encountered in inserting the needle, and especially in determining when the point of the needle was in proper position for the dis-

charge of the liquid. About 30 burrows were treated in one test and a subsequent examination showed that most of the borers had been killed by the resultant gas. The bark, however, was injured by the treatment. Where the liquid was injected into shallow burrows and came into contact with considerable areas of the inner bark more injury was done the tree than usually results from the direct work of a single borer.

Carbon disulphid can be injected with good results and with no apparent injury to the tree, into burrows that extend deep into the wood. Borers that penetrate beyond the reach of knife and wire can often be killed by discharging a little of the liquid into the open burrow and then plugging the opening with moist clay or some other substance. For injecting the liquid into such galleries, nothing is better than a medicine dropper with a curved point.

KEROSENE.

In September, 1914, 29 apple trees infested with roundheaded apple-tree borers were treated with kerosene, the liquid being applied liberally to the bark with a paintbrush over the regions where the borers were feeding. Four weeks later the trees were examined and 64 borers removed. Of these, 25 were dead and 39 alive. Severe injuries to the cambium and bark were beginning to show. A year later two of the treated trees were dead as a result of the oil application and others had large dead areas near the ground and around the base of the roots.

The conclusions derived from this test were that kerosene applied to the surface does not penetrate through the bark in sufficient quantities to kill all the borers and that its use in this way is dangerous to the health of the tree.

SODIUM ARSENATE WITH MISCIBLE-OIL CARRIER.

Late in the summer of 1918 a 10 per cent solution of sodium arsenate was mixed with a miscible-oil carrier and applied with a spray pump to the trunks of infested apple trees. The treatment was applied to 15 trees that averaged about 4 inches in diameter and contained borers of various ages and sizes. Early during the following spring the borers were removed from the trees, 28 specimens being obtained. Of these, 2 were dead and 26 alive and active. It could not be determined whether the two had died as a result of the treatment or from some other cause, and the treatment was considered of no practical value.

TESTS OF OTHER PENETRATING LIQUIDS.

In the summer and fall of 1917 a number of different penetrating liquids were used on infested apple trees in the experiment orchard

at Elkins. The liquids were applied with a paintbrush to the lower portion of the tree trunks as soon as it could be determined that all of the eggs of the season had hatched. The applications were made on August 16 to 17, and the trees examined for results 8 weeks later. The results of the treatments are set forth in Table XII. It should be borne in mind that all the borers considered in the table were newly hatched individuals that were feeding beneath only a thin layer of bark.

TABLE XII.—*Effect upon newly hatched roundheaded apple-tree borers of various liquids applied to the bark over the regions where they were feeding.*

Material used.	Number of trees treated.	Number of borers found—			Per cent of efficiency.
		Alive.	Dead.	Total.	
Nicotine sulphate, 1 part to 10 parts of water.....	60	26	20	46	43.5
Nicotine sulphate, undiluted.....	60	13	53	66	80.3
Raw linseed oil.....	60	22	16	38	42.1
Standard kerosene emulsion.....	60	28	28	56	50
10 per cent solution sodium arsenate, mixed with equal part of kerosene emulsion.....	60	15	31	46	67.4

It will be seen from Table XII that many borers may be killed by saturating the bark over where they are feeding with irritants and poisons of a penetrating nature, provided that the treatments are applied while the borers are still small and feeding in shallow burrows. All the materials used in the foregoing test killed a considerable number of borers, the undiluted nicotine sulphate giving best results. None gave complete control, and it is a question whether their use would be justified in orchard practice. Trees so treated would have to be gone over and wormed subsequently in order that entire freedom from borers might be assured.

SPRAYING WITH ARSENATES TO KILL THE ADULTS.

Feeding on the exposed surfaces of the apple and other host trees seems to be a general habit of the beetles. The bark of twigs and leaf stems and the tissues of the leaf are eaten. (Pl. IX, A, C.) Beetles were often observed manducating castings thrown out from the trees by larvæ, evidently for the moisture which the castings contained. The bark and leaf surface eaten away by one female totaled 6.9 square inches. This feeding habit suggests the use of poison sprays as a possible means of killing the beetles. In one small-scale experiment six newly emerged beetles were killed by applying a lead-arsenate spray to the foliage of a small apple tree over which they were caged. All died before the females were ready to oviposit.

In extreme cases of infestation it would probably be profitable to apply arsenical sprays to young apple orchards primarily for the

destruction of beetles of this species. Such sprays should be applied about 10 days after the blossoms have disappeared from apple trees and should consist of 4 or 5 pounds of lead arsenate paste to 50 gallons of water, or of the equivalent of this strength prepared with some other insecticidal poison. When trees reach a bearing age, the so-called first codling-moth spray will serve also to kill the beetles of the roundheaded apple-tree borer.

SUMMARY.

The roundheaded apple-tree borer is a native American insect that has been recognized as a serious pest of the apple, pear, and quince since the early days of orcharding in this country.

It occurs in the United States and Canada over most of the apple-growing region east of the Rocky Mountains.

In addition to the cultivated fruits named above, it breeds also in such wild trees as wild crab, hawthorn, mountain ash, and service. These native trees growing in woods or neglected fields often serve as centers in which the adults develop and from which they fly to near-by orchards to deposit their eggs.

In the woods and in orchards the insect is inclined to colonize, families or communities living in the trees of somewhat restricted localities. Often infestation in an orchard or in native woods will be confined for years to rather definite areas or spots. This habit is due largely to the inclination of the adult female to deposit her eggs near the place where she developed.

The common belief that borers of this species prefer to attack trees planted in new ground, in hilly situations, or in certain kinds of soils probably arises from the fact that such situations favor a more abundant growth of the native host trees of the insect. In these wild trees many adults develop and cause serious infestation of adjacent orchards.

About 95 per cent of the eggs from which the borers hatch are deposited in the bark within a few inches of the ground. The incubation period is about 16 days. The borers feed in the bark and wood for from one to four years and finally pupate at the end of an ascending gallery which extends up the trunk from a few inches to approximately 2 feet above the ground.

The burrows made in the bark and wood are broad and irregular in form. Often several borers work close together, as many as 25 or 30 having been found in a single tree. Infested trees become sickly in appearance. They are inclined to bloom freely and set heavy crops of fruit, but often die in an attempt to bring the crop to maturity. Young trees suffer most but trees of all ages are attacked. Trees of an orchard standing near woods are more likely to be injured by borers than those more distant from the woods.

In depositing her eggs the female beetle makes a slit in the bark with her mandibles and then inserts her ovipositor and places the egg between the bark and wood or between layers of the bark. About 9 or 10 minutes are required for the deposition of a single egg. Usually from 2 to 5 eggs are laid at a time. Probably all eggs are deposited by day, and the female in ovipositing shows a slight preference for the sunny or exposed side of the trunk, 65 per cent of the eggs being found in one case on the exposed side of the tree. In the latitude of West Virginia, the average number of eggs deposited by a single female is apparently from 20 to 30. Oviposition in a given locality extends over a period of from 50 to 60 days.

The larvæ begin to feed immediately after hatching and usually grow rapidly the first season. Feeding is continued until cold weather and is resumed again in the spring shortly before the blossoming time of the apple. The larva may spend from one to four years in the tree, this stage being of longer duration in the North than in the South. At French Creek, W. Va., 85 per cent of the larvæ remained in the trees two years before pupation, and 12 per cent three years. At Winthrop, Me., 25 per cent remained in the tree three years and 75 per cent four years.

The pupal stage lasts about 20 days and the period is about coincident with the blossoming time of apple. After changing to beetles the insects remain in the pupal chamber for from 5 to 10 days and then gnaw a circular hole through the bark at the upper end of the chamber and escape. The beetles appear in the South earlier than in the North. Between Demorest, Ga., and Munising, Mich., there was a difference of 75 days in the dates of the emergence of the first beetles. At French Creek, W. Va., beetles issued from the wood during two different years over a period of 30 days. Other years the period was shorter. May 12 was the earliest date for the appearance of a beetle in any year at French Creek, and June 23 was the latest date. A few beetles lived 60 days after issuing.

Pairing may take place at once or may be delayed 10 days after emergence. Eggs are laid soon after pairing. In an apple orchard containing 310 King, 341 Grimes, and 341 York Imperial trees, the Grimes were most severely attacked in four out of five years, nearly 50 per cent of all the eggs being laid in Grimes trees. This could be accounted for in no other way than that the borers showed a preference for this variety.

Experiments showed that the female beetles during oviposition are capable of flying to a considerable distance, but that they prefer to place their eggs in trees near the place where they themselves have developed. By preventing the development of adults in the orchard trees and in other trees growing within from 300 to 600 feet of the orchard, subsequent infestation was reduced 73.6 per cent.

The borers have few insect enemies, but woodpeckers play an important part in holding them in check. The downy woodpecker was observed removing borers from trees.

No easier and cheaper way of controlling borers was found than the old method of worming trees. The worming should be done as soon as possible after the last eggs of the season have hatched, and should be repeated in the spring following the blossoming time of apple trees. Worming can be done most effectively by two men working together on opposite sides of the tree. In this practice emphasis is placed on the importance of removing all breeding centers within or adjacent to the orchard.

Paints and various other kinds of tree protectors were used to prevent the adult females from ovipositing in the bark. Nothing of this nature was found that surpassed common white-lead paint in cheapness, ease of application, and effectiveness in controlling the borers. Young apple trees painted once annually for from four to six years showed no injury and the treatment gave a control efficiency of 74.3 per cent.

Various attempts to kill borers were made by applying to the bark of infested trees penetrating liquids of a poisonous or irritating nature. Nicotine sulphate, kerosene, kerosene emulsion, sodium arsenate in a miscible-oil carrier, and linseed oil were among the materials tested. None of these was effective on large borers that had penetrated deep into the tree, but most of them killed a considerable percentage of young borers that were still feeding in shallow burrows.

The beetles feed rather freely upon leaves and the bark of twigs. Tests made indicate that it is possible to kill the beetles by spraying with arsenicals. Sprays for this purpose should be applied to young orchards within 10 days after apple blossoms have disappeared. In bearing orchards what is known as the first codling-moth spray will be effective also against the adults of the roundheaded apple-tree borer.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 872

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.

November 11, 1920

INSECT CONTROL
IN FLOUR MILLS

By

E. A. BACK, Entomologist in Charge of Stored-Product
Insect Investigations

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MILL INSECT CONDITIONS BETTERED.

The control of insect pests in flour and cereal mills has become a very important feature of food conservation and of mill construction and operation. The cleanliness of many of the well-lighted, concrete mills, such as are being built more frequently now than ever before, and their comparative freedom from pests, are emphasized by the conditions that exist in old-type structures. These latter offer insects every advantage in their fight against the miller. It is true that many of these older mills are established in rambling, loosely constructed buildings that can be neither properly cleaned, from the standpoint of insect destruction, nor made tight for the application of successful control measures. Fortunately the losses caused by insects to the mill owners and the advantages of modern construction are working hand in hand to bring about a constant change for the better. With modern equipment installed in buildings erected with a view to suppressing insects, more millers are joining the ranks of those who know that they can control insects and offer the public a product reasonably free from infestation.

INCENTIVE LEADING TO INSECT SANITATION.

Owners of flour mills are frequently blamed by brokers, retail grocers, and the public at large for insect infestations found in their products when these appear on the market or in the home. Sometimes the miller is to blame; often he is not. It is, however, within his

power, if he is the owner of a well-constructed mill, so to control pests that he can state, with honesty, that the product he places upon the market is reasonably free from insects, including their eggs, and that if infestation develops soon after his product has been warehoused or otherwise disposed of, the infestation is due to one or more of several known conditions for which he is in no way responsible.

There has persisted among many millers, as well as consumers, the belief that the egg or "germ" of insects is within the grain at the time it enters the mill and that it goes uninjured through the milling process to lie dormant in the finished product until such time as conditions of warmth and moisture favor its development. This belief rests upon a false foundation. The ordinary destructive insects that infest grain or flour or any cereal product lay eggs large enough to be readily seen by an experienced eye once they are separated from the host material. They are all so large that they can not pass through the meshes of No. 10 XX silk bolting cloth. Since this is true, even badly infested flour can be reprocessed and rendered absolutely free from pests if bolted through a No. 10 XX or finer cloth.

It is possible to produce flour entirely free from infestation as it comes from the bolting machines. If it is sacked in containers upon which no eggs have been laid or in which no larvæ are present, and is stored in a warehouse in which there is no infestation, it will leave the mill free of infestation. If such a product shows infestation by the time it reaches its destination, it has become infested while en route. To guarantee a product leaving the mill establishment as free from infestation is so entirely within the bounds of reason that one wonders whether certain millers should be permitted to ignore insect infestations and put upon the market supplies that are invariably infested.

MEDITERRANEAN FLOUR MOTH.¹

MEDITERRANEAN FLOUR MOTH MOST SERIOUS MILL PEST.

While there are many insects that may become troublesome in flour mills, it is the Mediterranean flour moth alone that seriously affects the operation of the mill and has brought with its advent from Europe into the mills of the United States losses that have forced millers to consider insect suppression. The weevils and other granary pests which are brought into mills with grain, and the flour beetles or "bran bugs" which become established in practically all mills sooner or later, will not be discussed in this bulletin, though they must be taken into consideration by millers. The remedial measures advocated for the suppression of the Mediterranean flour moth, with cleanliness, will hold these nonwebbing insects in check.

¹ *Ephestia kuehniella* Zell.

MEDITERRANEAN FLOUR MOTH AN INTRODUCED PEST.

The Mediterranean flour moth is a pest introduced into this country from Europe. Until 1877 it was little known in the Old World, but in that year it was discovered in a flour mill in Germany. Later it spread to Belgium and Holland, and in 1886 was found in England. In 1889 it was found in destructive numbers in Canada. The Mediterranean flour moth first appeared in the United States in 1892, when it was found infesting flour mills in California. Since that time its spread has been fairly rapid. It was found established in New York and Pennsylvania in 1895, in Minnesota in 1898, in Wisconsin in 1900, and in Michigan in 1902. By 1904 it was reported from other States, including Indiana, Illinois, Montana, Colorado, Ohio, and Iowa. Since 1904 its spread has been very rapid, until at the present time the Mediterranean flour moth is present in practically every milling center and may be found in warehouses throughout the country where flour and cereal products are stored.

LOSSES DUE TO INFESTATION.

Millers have reason to dread this pest, since the webbing habit or the larvæ sometimes completely stops the machinery and always, sooner or later, necessitates the expenditure of time and money to keep the pest under control. It is difficult to obtain definite estimates of losses caused by the Mediterranean flour moth, but for mills of 1,000 barrels capacity it is seldom less than \$100 to \$200 a year. The average loss, according to Dr. F. H. Chittenden, "due to closing down the mill and cost of treatment seems to be not far from \$500 for each fumigation, 'to say nothing of the loss to business,' according to one Kansas milling firm. An estimate of \$1,000 for two fumigations would not be far from right, although others estimate \$2,000, and still others—owners of larger mills—claim it to be \$5,000 a year." Prof. G. A. Dean has stated that the loss to Kansas grain and mill interests may be placed very reasonably at "not less than \$2,000,000 annually." It is evident that the loss to flour and cereal mill owners throughout the country is enormous and far beyond the average belief.

TRANSFORMATIONS OF THE MEDITERRANEAN FLOUR MOTH.

The adults of the Mediterranean flour moth are moths or millers with a winged expanse of a little less than 1 inch. The forewings are pale leaden gray with black markings, as shown in figures 1 and 2, although sometimes the wings are much darker. These parent moths are very tame, and when resting quietly upon various portions of the mill and stocks assume a peculiar attitude, illustrated

in figures 1, *b*, and 2. The female moth lays eggs in accumulations of flour, up and down elevator legs, throughout spouts, around dust collectors, in bolters, purifiers, etc. From these eggs hatch the larvæ or worms. When full grown, the larvæ are about half an inch long and are whitish or pinkish in color, with minute black dots and fine hairs, as shown in figure 1, *c*, *e*. When full grown the larvæ spin cocoons in which they transform into the reddish brown pupæ shown in figure 1, *d*. From these pupæ emerge the parent moths of the next generation.

LENGTH OF LIFE FROM EGG TO ADULT.

Dean² states that when the temperature ranges from 85° to 90° F., the eggs of the moth hatch in about 3 days, the larvæ become full grown in about 40 days, and the pupal stage requires from 8 to 12 days

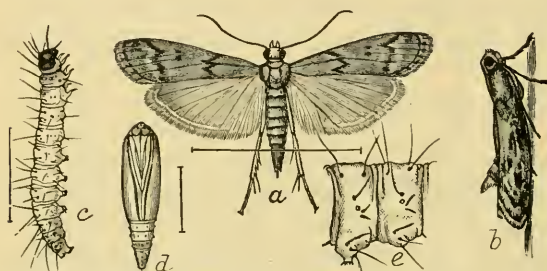


FIG. 1.—Mediterranean flour moth: *a*, Moth; *b*, same from side, resting; *c*, larva; *d*, pupa; *e*, abdominal segments of larva. The hair lines by *a*, *c*, and *d* represent the actual length of the forms. (Chittenden.)

more. Under ordinary flour-mill conditions about 9 weeks are required for the pest to pass through its life cycle from egg to adult. Length of the life cycle varies greatly with the temperature. At temperatures lower than 55° F. activity is sus-

suspended. During most favorable temperature conditions, 24 days has been found by Chittenden³ to be the minimum required for larval development.

LARVAL HABITS MAKE MOTH MOST SERIOUS PEST.

The Mediterranean flour moth is the most serious of all mill pests, not so much because of the food values it actually consumes, but because the larvæ or worms construct in the flour silken tubes in which they live, spin a fine silken thread wherever they crawl, and spin cocoons in and about the machinery and stock. As they grow older they spin increasing amounts of silk until, when they are full grown, the quantity of web they spin in crawling about machinery, sacks, etc., in search of a suitable place to spin cocoons is enormous, and causes a bad webbing or matting of the flour. These masses of webbed flour receive during the operation of the mill fresh layers of flour, which

² DEAN, G. A., MILL AND STORED-GRAIN INSECTS. Kans. State Agr. Coll. Exp. Sta. Bul. 189, p. 226-227. July, 1913.

³ CHITTENDEN, F. H., THE DEVELOPMENT OF THE MEDITERRANEAN FLOUR MOTH. In U. S. Dept. Agr. Div. Ent. Bul. 6 (n. s.), p. 85-88, 1896.

in turn are matted together by the burrowing and crawling larvæ. Finally the webbed masses (fig. 3) become so large that they choke or clog the machinery and force the miller to shut down. There is then nothing left for the miller to do but set his men to a thorough cleaning out of all machinery, spouts, etc.

HOW MILLS BECOME INFESTED.

The Mediterranean flour moth gains access to the majority of mills through the medium of secondhand or returned sacks. The moths occur in blending plants, where they lay eggs on old sacks, and the lar-



FIG. 2.—An adult Mediterranean flour moth resting naturally upon a plank. Notice characteristic posture. These moths are so tame and remain so quiet that they often escape attention. (Dean.)

væ then hide and spin cocoons in the seams and folds, thus making it easy for the pest to be carried from place to place. The installing of secondhand machinery that has not been properly fumigated is also a means of dissemination. These are the main avenues of entry to uninfested and new mills that any miller can close if he will. The miller is, however, more or less helpless to prevent infestations when his mill is located in a center of general infestation, as the adult moth can fly from building to building. Of course, all returned sacks are apt to bring infestations.

WHERE TO LOOK FOR EARLY INFESTATIONS.

Millers who fear that the Mediterranean flour moth will become established in their mills and wish to apply remedial measures as

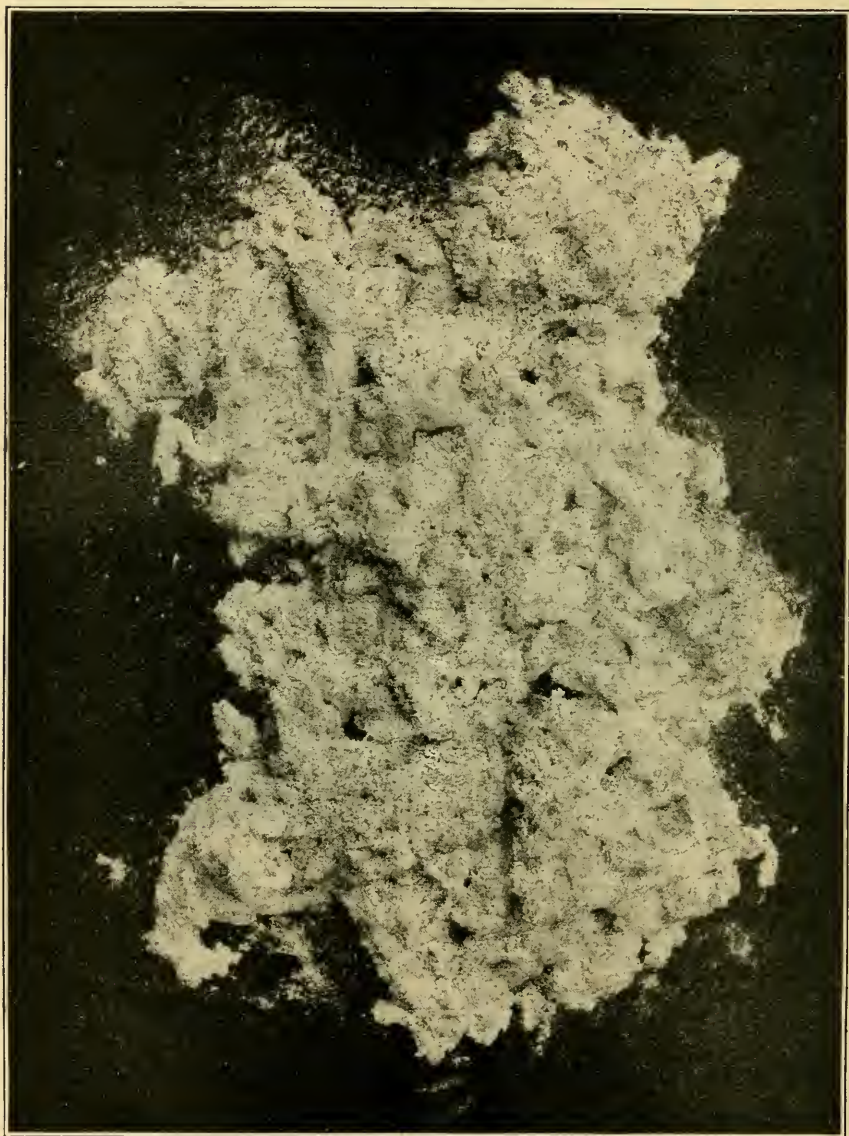


FIG. 3.—A clump of matted flour showing result of the webbing habit of the larvæ of the Mediterranean flour moth. (Chittenden.)

early as possible should keep an especially close watch for the pest in places where it is apt to appear first. These are in elevators, purifiers, and the machinery carrying and handling the warm sweet

or germ stocks. During the cooler months the pest is often found in and about the dust collectors, especially if these are warm or are taking heat from the rollers. It should be taken for granted that returned or secondhand sacks are infested and must be treated before being taken into the mill proper. The moth is too widely distributed to-day to justify a miller in taking chances with these sacks.

METHODS OF CONTROL.

The control measures for the Mediterranean flour moth, and, incidentally, for other mill pests, may be divided into three classes: Preventive, including attention to cleanliness; natural control, dealing with nature's attempt at control by parasites; and artificial control, including destruction of pests by fumigation, heat, and cold.

PREVENTIVE MEASURES.

The need for cleanliness can not be overemphasized. Insects prefer to lay eggs upon and develop in flour and cereals lying in undisturbed darkened situations. Insects are most abundant in such places. The frequent cleaning out and destruction of such material nips in the bud what may become an infestation causing a loss many times greater than the cost of cleaning. Experienced millers know this.

FREQUENT CLEANING.

A large proportion of insect infestation in flour mills is due directly to lack of cleanliness. This does not mean that the product coming from such mills is unclean, but that flour is allowed to accumulate for long periods in various places throughout the machinery and buildings to serve as a rich breeding ground for pests, which multiply rapidly and spread to all parts of the mill. It has already been stated that under ordinary flour-mill conditions during the warmer months, the Mediterranean flour moth requires about nine weeks for each generation. Certain other mill pests require from 5 to 7 weeks to complete their life cycle. It is, therefore, evident that if mills are given a thorough cleaning about every five weeks throughout the summer months, much good will be accomplished in reducing pests, for in destroying the stocks removed from undisturbed or dead spaces, many insects are captured and destroyed also. Labor to brush out and remove accumulation of stocks from elevator boots and flour conveyors, and to destroy them by burning is labor well spent. Going over elevator legs with a spout maul, or the use of elevator and belt brushes (fig. 4), will dislodge much infested material and aid greatly in removing accumulations

GOOD CONSTRUCTION.

If walls and ceilings are smooth and well painted or whitewashed, they are kept clean more easily, and offer no places for flour to lodge or insects to breed. Rough stone or brick walls (fig. 5), or those made of matched boards (fig. 6) offer many hiding and breeding places. Floors should be of concrete, where this is possible, for board

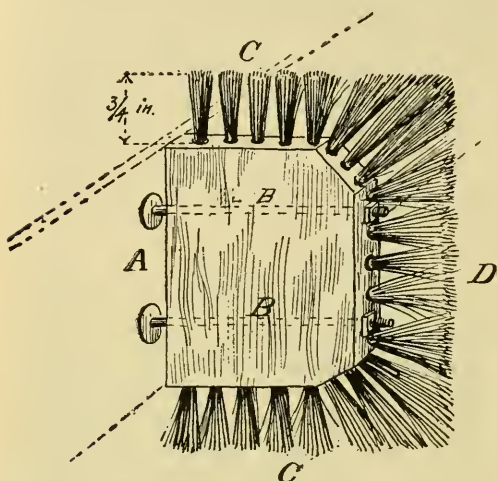


FIG. 4.—Elevator and belt brush for cleaning elevators infested by the Mediterranean flour moth. It is made by taking a piece of $1\frac{1}{2}$ -inch board of same dimensions as elevator cups, fastening bristles to three sides. Side A is fastened to elevator belt with flat-headed bolts running through board, as shown at BB, the bolts being $\frac{1}{4}$ or $\frac{3}{8}$ inch. Bristles on sides CC should be $\frac{3}{4}$ -inch long, but those at D should be longer, so that a good brushing to outside of elevator may be secured. Such a brush can be made to fit any elevator. (Chittenden.)

floorings offer shelter, unless unusually well constructed. Floors and walls should be so joined that there is no opportunity for accumulations along sides and corners. Well-cemented basements that are light and dry are an aid.

Machinery should be placed high enough to allow frequent and thorough cleaning beneath it. Where practicable the bottoms of flour conveyors should be of metal and rounded, so as to permit the least amount of flour or meal to accumulate along the side and at the ends. The hoppers of the rolls should be constructed of cement and in

such manner as to allow no flour to accumulate in inaccessible places.

USE OF LIME.

A liberal use of air-slaked lime in dark corners of damp basements will not only serve as a repellent to insects, but will also tend to destroy some of the objectionable odors and sweeten the air.

CARE OF SACKS AND BAGS.

New sacks and bags should not be stored in packing rooms or in any place where they become dusted with flour or cereal products, for in this flour dust various mill pests can breed and become established ready to attack stocks packed in the sacks. This is an important point often overlooked. Secondhand sacks should never

be taken into the main mill building before they are thoroughly disinfected. It has already been stated that in the majority of cases the spread of moths from mill to mill is traceable directly to the use of untreated secondhand sacks. Such sacks should be stored in a

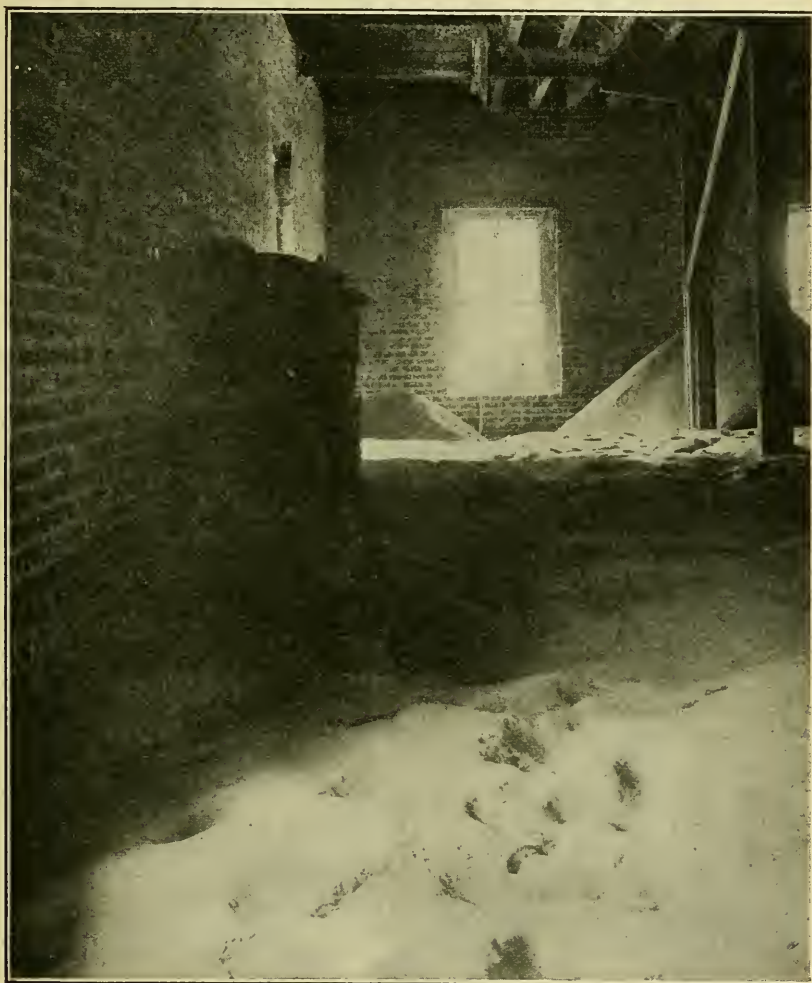


FIG. 5.—View in basement of flour mill. Note accumulations of webbed flour on floor, on bundles of twine, clinging to brick walls, and hanging from overhead beams. The flour in the foreground on floor is badly webbed. Such conditions are not allowed to exist where control measures are put into successful operation.

small, tightly constructed house separated from any part of the mill, and there treated either by heat or fumigation. This may involve extra handling but should become a part of the routine of protection against pests.

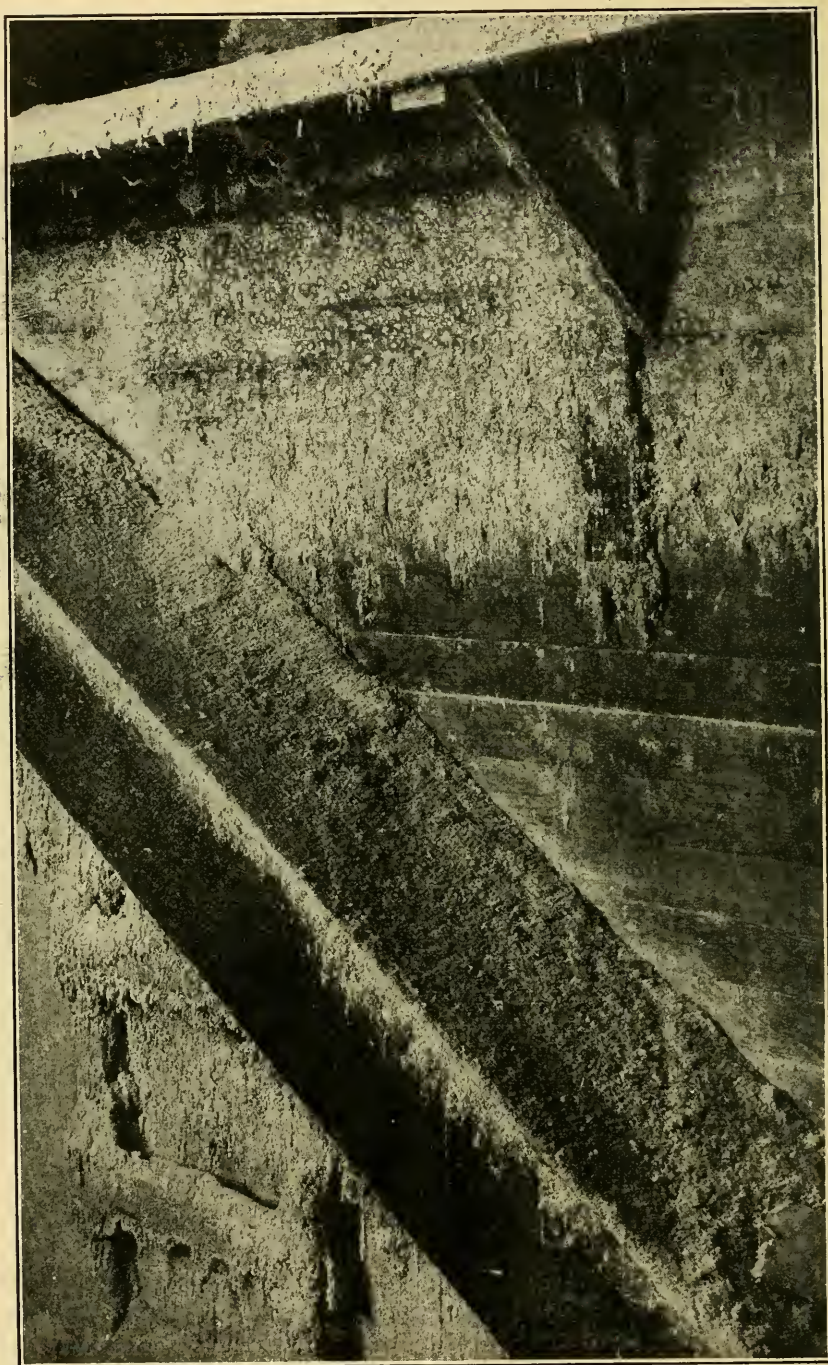


FIG. 6.—Portion of side of very poorly kept flour mill. Note accumulations of flour, much of which is webbed by the flour moth, on side walls, timbers, and ladder. Such neglect breeds trouble.

CLEANLINESS IN WAREHOUSE ROOMS.

Warehouse rooms, as well as the mill proper, should be kept as clean as possible. After each movement of stocks the floor and walls should be cleaned to prevent insects present from holding over to attack a new stock. Neglect of this simple precautionary measure has resulted in a more rapid infestation of warehouse stocks than is generally appreciated.

NATURAL CONTROL BY PARASITES.

In many mills the Mediterranean flour moth is attacked by insect parasites, *Habrobracon hebetor* (Say) and *Omorga frumentaria* (Rond.), but in no case are these of sufficient importance to warrant a miller depending entirely upon them, although at times they may prove a valuable control factor. They are not a dependable factor in any part of the United States. In a successful fight against the flour moth, control by parasites should not be relied upon.

ARTIFICIAL CONTROL MEASURES.

Since the spread of the Mediterranean flour moth from Europe to the milling centers of the United States experimental work has been conducted to determine the most satisfactory methods of control. From the various processes advocated from time to time, such as fumigation with sulphur, carbon disulphid, tobacco fumes, formaldehyde gas, etc., there have finally emerged two control measures that have now proved their value. These are fumigation with hydrocyanic-acid gas and control by heat. Where these can be intelligently and thoroughly applied results can be guaranteed. Heat is unquestionably the cheapest and simplest agent of control now known. Millers have had varying results in attempts to control the moth with freezing temperatures.

HYDROCYANIC-ACID GAS TREATMENT.

Fumigation with hydrocyanic-acid gas, while effective, is a disagreeable method of control. The gas generated is deadly to man, as well as to insects, and precautions must be taken to safeguard the lives of laborers and dwellers in closely associated buildings. It is assumed for the purposes of this bulletin that no milling concern will attempt fumigation with hydrocyanic-acid gas without calling in the services of an expert familiar with the process.² It may be added that where it can be used, hydrocyanic-acid gas fumigation is perfectly safe when conducted under the immediate supervision of a

² For more complete information regarding the use of this gas, write to the U. S. Department of Agriculture for publications.

properly informed and careful person. Success in the use of hydrocyanic-acid gas is in proportion to the tightness of the mill to be fumigated. Many old loosely constructed mills can not be fumigated successfully, even by an expert fumigator, because they will not hold the gas sufficiently long. In such mills one can not hope to do more than reduce the moth temporarily by any one fumigation. In tight structures two thorough fumigations applied dur-



FIG. 7.—Wooden oil barrel, well soaked with water previous to use in fumigation, set in galvanized iron washtub partially filled with water to which have been added several handfuls of sal soda.

ing warm weather within a short time of each other, as discussed on page 27, have been known to exterminate the moth. In rare cases one fumigation has exterminated the moth.

PRECAUTIONARY MEASURES.

Although it has been stated above that no mill concern should attempt fumigation without the assistance of a chemist, entomologist, or other person well informed regarding the process, attention should be called to several precautions that must be taken to guard against fatalities arising from inexcusable carelessness and ignorance. Very few deaths have occurred as a result of fumigation with hydrocyanic-acid gas as a mill fumigant, and those that have occurred have been due to

criminal neglect on the part of those responsible for the fumigation.

Where mills are in buildings well isolated from other buildings, owners need not consider neighbors in their plan for fumigation, but when the fumigation is to be conducted in one of a series of buildings, such as occur in city blocks, owners of property immediately adjoining must be informed of the intention to fumigate and arrangements made with them whereby they will be ready to vacate their stores or offices should the fumes penetrate the intervening walls. The odor of hydrocyanic-acid gas is easily detected, and the person in charge of

fumigation should advise regarding the need to vacate. Persons should be advised not to remain in rooms closely associated with rooms being fumigated if the odor of the gas can be detected. In numerous fumigations persons have remained at their work even when the odor of the gas was very pronounced, and workmen have been known to carry on trucking operations in warehouses where the odor of the residual gas after fumigation was so strong as to give the writer of this bulletin unpleasant feelings. Rooms adjoining those being fumigated should be kept well ventilated, but even then, to remain in them when the odor of the gas can be detected may lead to fatalities directly chargeable to the fumigator. To attempt fumigation without the approval and cooperation of those controlling the occupants of adjoining buildings may lead to fatalities directly chargeable to criminal neglect on the part of the person conducting the fumigation.

Guards should be placed at entrances that can not be closed by means of reliable locks to thoughtless intruders. Only trusted men should be employed to assist in any process of fumigation, and this holds particularly true of the person or persons left on guard. One man, at least, is known to have been killed because he was not informed of the fumigation, returned for night work, and entered through an unlocked door left temporarily unguarded by a sleeping guard. A genuine responsibility rests upon a person conducting fumigation and he should discharge his duties with all seriousness. He should choose as helpers only the most intelligent and trustworthy employees.

PREPARATION OF MILL FOR FUMIGATION.

Preliminary cleaning.—In fumigating a mill the greatest loss of time is caused by the need for preliminary cleaning; the fumigation can be done between Saturday night and early Monday morning or within any period of 24 hours' duration. The reason for thorough cleaning and destruction of flour and accumulations from various parts of the mill is primarily to leave in the mill at the time of fumigation no masses of stocks which the gas must penetrate to reach all the insects. Hydrocyanic-acid gas, deadly as it is, can not be depended upon to reach and kill all moths, pupæ, eggs, and larvæ if these are buried beneath several inches of well-packed flour, such as often occurs in dead spaces of machines, in floor cracks, basements, etc. The removal and destruction by burning of such accumulations which, as has been stated already, are favored by pests as feeding and breeding places, destroy large numbers of insects, as well as leave the mill in a condition to be fumigated to best advantage.

Make mill as tight as possible.—The mill should be made as tight as possible, so that the gas generated can not escape before it has had a chance to kill the flour moth. Broken windows, ventilators,

and cracks about window frames can be made tight by pasting strips of paper over them. Even an occasional open window and doorways, stairways, and elevator shafts can be fairly well sealed by the use of heavy paper applied in several thicknesses by paper hangers. All

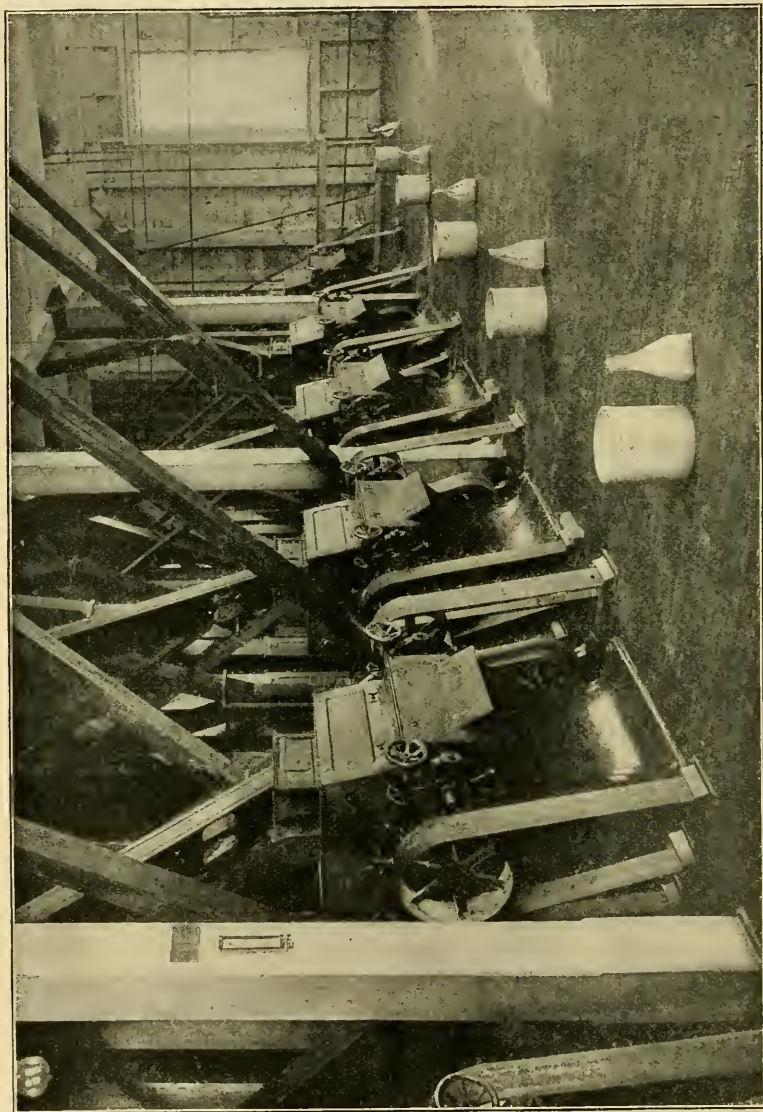


FIG. 8.—First floor of a flour mill, showing the proper arrangement of the generators and the bags of cyanid for hydrocyanic-acid gas fumigation where the bags are to be dropped by hand. (Dean.)

such openings must be closed before fumigation is attempted or failure will result. As the gas has a tendency to rise, each floor should be treated as a unit by closing such openings as those formed by elevator shafts, stairways, etc. The small openings through which

belting passes and similar openings in the floor can be sufficiently well closed by crowding pieces of sacking firmly into them.

CHEMICALS NECESSARY FOR FUMIGATION.

The chemicals necessary for the generation of hydrocyanic-acid gas are potassium or sodium cyanid,³ sulphuric acid, and water.

Cyanid.—Either potassium cyanid or sodium cyanid can be used in fumigation, but trade conditions have made sodium cyanid more available for use and, as it is just as good and slightly cheaper, it is recommended. For a full discussion of the relative values of potassium and sodium cyanid for fumigating purposes, see Bulletin 90 of the Bureau of Entomology. Sodium cyanid for fumigation purposes should be 96 to 99 per cent guaranteed purity. The volume of gas liberated is in direct proportion to the purity of the cyanid, hence too much stress can not be placed on purchasing high-grade cyanid. Protection can be had by purchasing a cyanid guaranteed under the Federal insecticide act; the analysis on the label should show that the cyanid is at least as pure as follows:

Sodium cyanid (NaCN), 96 to 99 per cent, analysis.

	Per cent.
Cyanogen (CN), not less than-----	51.3
Sodium (Na), not more than-----	43.7
Inert substances, not more than-----	4.0
Chlorids, not more than-----	1.4

High-grade cyanid can be purchased in tin cans containing 50, 100, or 200 pounds. For ease in handling and preparing doses, it is convenient to purchase brands of cyanid in which the material is divided into lumps weighing approximately 1 ounce each. Cyanid decomposes slowly when exposed to the air, hence such cyanid as remains unused after a fumigation should be protected by being placed in an airtight receptacle. Where this can not be done, the filling in of the original container with firmly packed sacking will greatly retard decomposition.

Sulphuric acid.—Commercial sulphuric acid (H_2SO_4) 92 to 94 per cent pure (66° Baumé), free from nitric acid, arsenic, lead, and zinc, should be used. It may be made from pyrites or pure brimstone, so long as impurities are eliminated. Acid is usually purchased in iron drums containing 800 to 1,500 and 2,000 pounds, though when used in smaller quantities it can be had in glass carboys of about 100 pounds capacity. Pure acid is colorless and about twice as heavy as water; its specific gravity is 1.83. When stored in iron drums it

³ Recent developments in liquid hydrocyanic acid indicate that sooner or later its use will replace this long established method of generating gas by the mixing of chemicals in containers.

frequently has a milky white color, especially at the bottom of the drum, due to the presence of sulphate of iron resulting from the

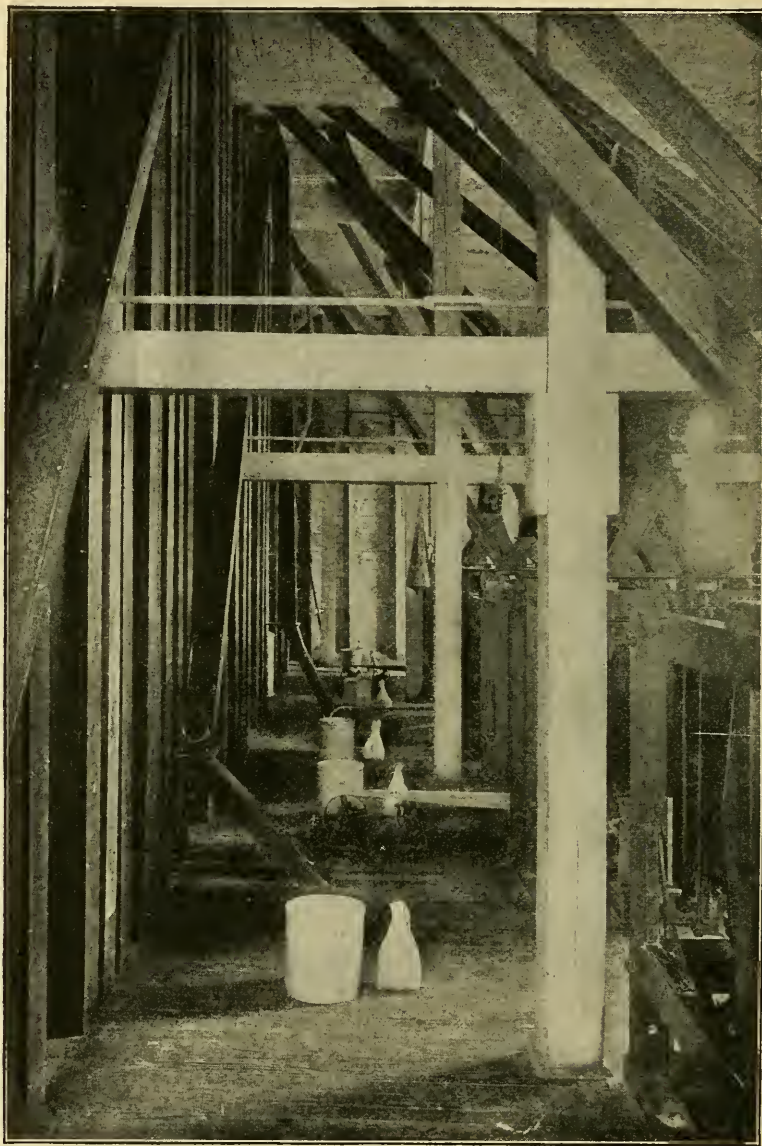


FIG. 9.—Second floor of a flour mill, showing the proper arrangement of the generators and the bags of cyanid for hydrocyanic-acid gas fumigation where the bags are to be dropped by hand. (Dean.)

action of the acid upon iron either before or after the acid is placed in the drum. This sediment does not affect the value of the acid

unless present in excessive quantities. In estimating the amount of acid required it is sometimes convenient to know that $1\frac{1}{2}$ pints of acid

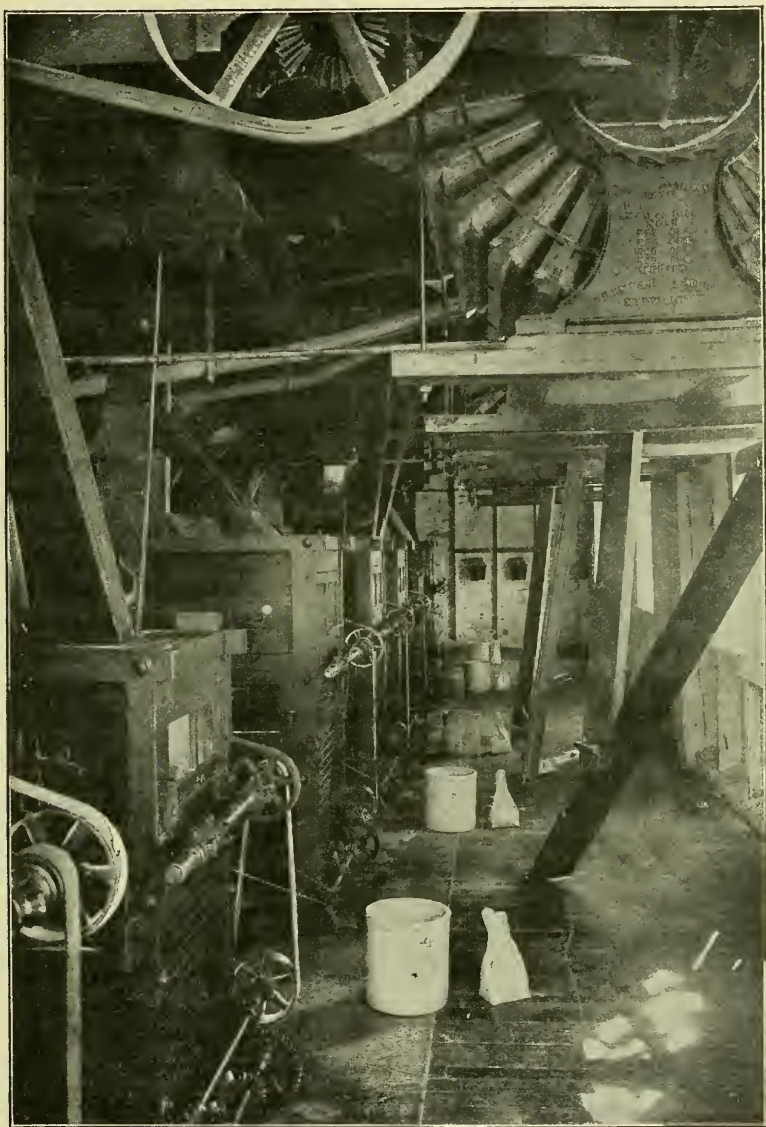


FIG. 10.—Third floor of a flour mill, showing the proper arrangement of the generators and the bags of cyanid for hydrocyanic-acid gas fumigation where the bags are to be dropped by hand. (Dean.)

by liquid measure is required for each pound of cyanid when the following formula is used.

$$183545^{\circ}-20-3$$

PROPORTION OF CHEMICALS.

Hydrocyanic-acid gas is generated by mixing in proper proportion sodium cyanid, sulphuric acid, and water. These should be combined as follows:

1 ounce, by weight, of sodium cyanid.

1½ ounces, liquid measure, of sulphuric acid.

2 ounces, liquid measure, of water.

This is known as the 1-1½-2 formula. Slightly varying formulas have been recommended, but this 1-1½-2 formula yields good results.

EQUIPMENT FOR GENERATING GAS.

The equipment for generating gas may be very simple and should include the following:

Containers for generating the gas.—For mill fumigation, 4-gallon earthenware stone crocks, well glazed, such as may be purchased at any hardware store, have proved very satisfactory. Four-gallon crocks (see figs. 8 to 14) will receive a charge containing a maximum of 4 pounds of cyanid. Fumigation does not injure them for other purposes provided they are properly cleaned. Where very large spaces are to be fumigated strong water-tight wooden barrels have frequently been used. Untreated oil barrels in good condition have served for several fumigations without marked deterioration, where care is taken to add the acid slowly and to rinse thoroughly after using. A 50-gallon barrel will accommodate with ease a charge of 20 to 30 pounds. Containers holding larger quantities of solution are more difficult to remove and empty than smaller ones, and this is an important item. Good barrels sufficiently small to fit easily into an ordinary galvanized-iron washtub (fig. 7) and receive charges of 15 to 30 pounds of cyanid are very satisfactory when buildings are so arranged that they can be easily removed and emptied. If the tubs are partly filled with water to which have been added several handfuls of ordinary salsoda, there is no danger that the acid will spill out onto the floor during the chemical reaction which produces the gas, and the handles of the tub make it easy for two men to remove the tub and barrel at the same time after fumigation.

Measuring and carrying equipment.—Scales are needed for weighing cyanid. Glass graduates of 16 or 32 ounce capacity should be used for measuring acid and water. One or two gallon granite ware cups and pitchers are very convenient and safe for carrying acid. Ordinary granite ware buckets in good condition can be used very satisfactorily in carrying acid from carboys to generators, though these should be carefully washed immediately after use and not allowed to stand with acid in them. Containers of tin must not be used.

Sacks.—Sacks for holding the individual charges of cyanid are needed. When 4-gallon crocks are used common manila paper sacks, sizes 8 and 10, such as may be had of any grocer, are the best

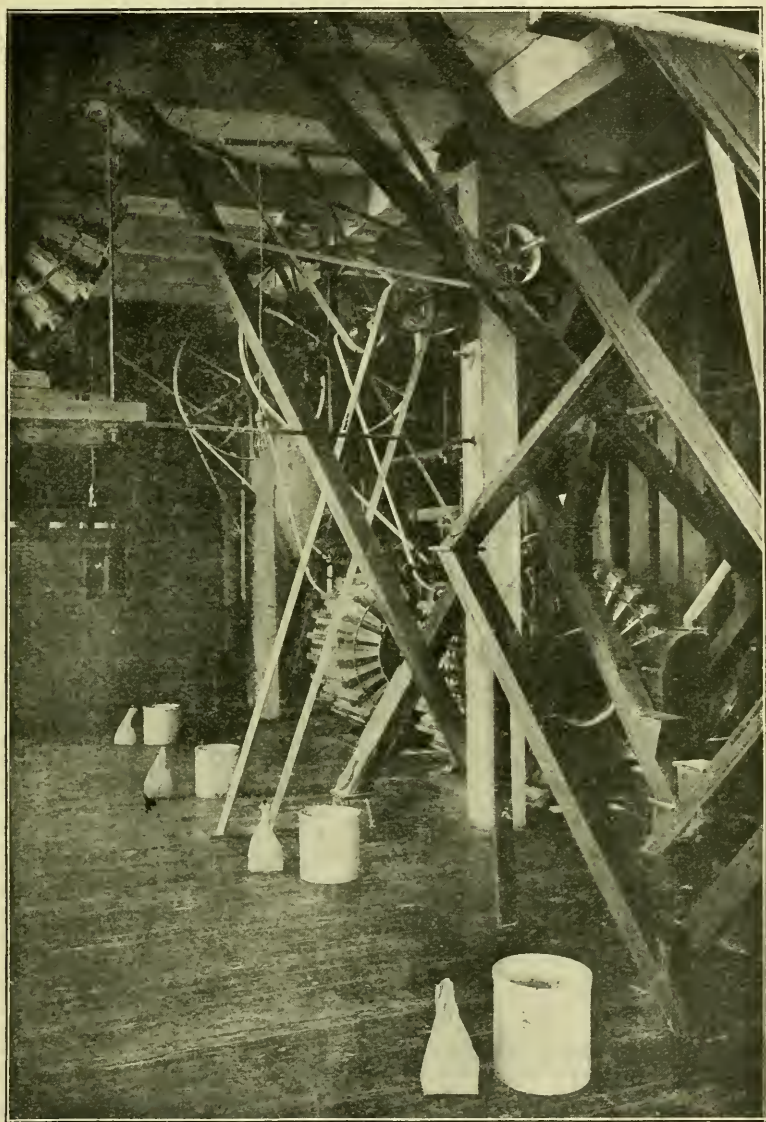


FIG. 11.—Fourth floor of a flour mill, showing the proper arrangement of the generators and the bags of cyanid for hydrocyanic-acid gas fumigation where the bags are to be dropped by hand. (Dean.)

in which to place the cyanid. The cyanid is placed in the smaller sack, after which the smaller sack is slipped within the larger one. Sacks of heavy or heavily glazed paper should not be used, for

they retard the action of the acid upon the cyanid. Where larger doses must be carried old bran sacks may be used for the cyanid.

Protection against burns and charring.—Persons engaged in fumigation according to the method described in this bulletin invariably receive slight injuries to their clothing in the form of acid burns due to spattering and dripping of acid. Only the oldest clothing should be worn. A saturated solution of common washing soda crystals (sodium carbonate) should be at hand ready to apply to hands, face, or floor to neutralize acid spatterings that may occur. When acid is purchased in iron drums a sufficient number of 5 to 10 gallon glass carboys in the usual wooden frames to hold all acid.

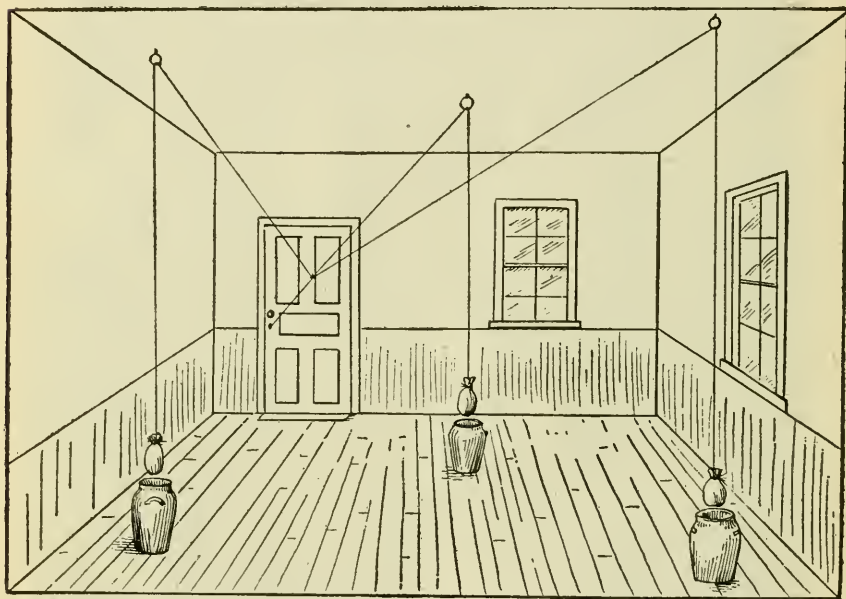


FIG. 12.—Diagram showing "stringing method" used in generating hydrocyanic-acid gas. The number of generators connected with the main cord may vary to fit the need of individual cases. (Chittenden.)

needed for the fumigation, should be provided to hasten the measuring of the acid. To guard against injury to the mill flooring, the acid should be measured outside the mill; or if this work is done within the mill old sacks and sawdust should be used liberally to prevent any acid spilled during the work from damaging the floor.

Provision for ventilating rooms after fumigation.—Care should be taken to provide for the ventilation of rooms or buildings after fumigation. It is dangerous to enter rooms to open windows from within although experienced fumigators often take such risks. Ingenuity can be depended upon to discover a way to open windows, transoms, or skylights from the outside by means of cords or wires.

ESTIMATING SPACES.

After a decision to fumigate has been made, the amount of space to be fumigated must be determined by securing the inside measurements of the length, width, and height of each room. No deductions should be made for machinery, bins, etc.

AMOUNT OF CHEMICALS NEEDED.

Once the cubic contents have been determined the amount of chemicals needed can be calculated easily. In the treatment of single tight rooms 1 ounce of cyanid is recommended for each 100 cubic feet of space. Where a reasonably tight mill has 4 or 5 floors the following standard, suggested by Dean, should be followed, as the gas is light and has a tendency to concentrate on the upper floors. Use 1 pound of sodium cyanid to each 1,000 cubic feet of space in the basement, to each 1,200 cubic feet of space on the first floor, to each 1,300 cubic feet of space on the second floor, to each 1,500 cubic feet of space on the third floor, and to each 1,600 cubic feet of space on the fourth and fifth floors. When buildings are rather loosely constructed, a larger amount of cyanid will be needed, but no directions can be given that will be as useful in determining the amount necessary to offset the looseness of individual mills as one or two experimental fumigations.

According to the $1-1\frac{1}{2}-2$ formula recommended on page 18, for each 100 pounds (1,600 ounces) by weight of cyanid required there will be needed also 2,400 fluid ounces of sulphuric acid.

NUMBER OF GENERATORS REQUIRED.

If 4-gallon crocks are used for generating the gas, one crock will be needed for each 4 pounds of cyanid required, or for each 6,400 cubic feet of space, when 1 ounce of cyanid is used to each 100 cubic feet of space. Where larger generators are used, as discussed on page 18, determine the amount of cyanid to be used in each container and use it to divide the total cyanid required for the building or room to secure the number of generators needed. It is always well not to overtax the capacity of a generator.

PLACING OF GENERATORS.

In placing the generators or jars, care must be taken to have them sufficiently distant from machinery, belting, sacks, walls, etc., so that there may be no danger of injury from spattering during gas generation. The reader is directed to examine carefully figures 8 to 11 for illustrations of how best to arrange generators. In using crocks it is always best to place beneath each crock some old sacking or papers, as not infrequently there is a slight spattering of the floor

close to the crocks during the chemical action which forms the gas. This is particularly true when a maximum charge for any container is used.

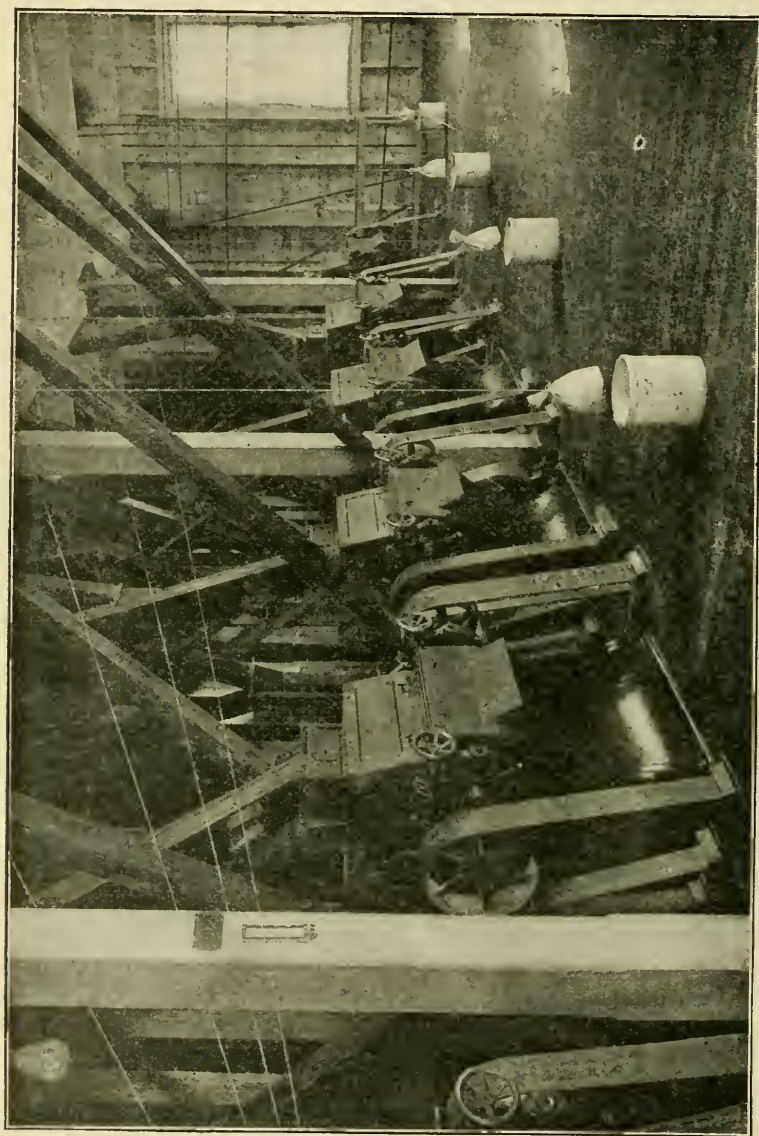


FIG. 13.—First floor of a flour mill, showing the proper arrangement of the generators and the bags of cyanid for hydrocyanic-acid gas fumigation where the string system is to be used. (Dean.)

ORDER OF ASSEMBLING CHEMICALS FOR FINAL GENERATION OF GAS.

Having decided upon the number of generators for each floor and the amount of charge for each, the generators should be well distributed. The proper amount of water should then be measured out

and poured into each container. The acid should always be added to the water and never vice versa. The mixing of water and sulphuric acid generates heat; hence care should be taken to pour the acid slowly into the water to prevent too rapid a rise in temperature, which might cause a cracking of the crocks. As the gas is formed best when the mixture of acid and water is warm, the acid should not be added until just before the fumigation is started. As soon as the acid is poured into the generators the cyanid, which has already been weighed out into proper amounts and placed in sacks, should be distributed, one sack by each generator, as illustrated in figures 8 to 11.

DROPPING OF THE CYANID.

By this time everything should be in readiness for the generation of the gas. The building has been tightly closed, except for the doors or windows through which those who drop the cyanid will leave the building. Provision has been made for ventilating after fumigation (p. 20), the building has been cleaned (p. 13), made tight (p. 13), and manholes, slide doors, etc., in spouts, elevator legs, etc., have been opened, and all persons have been accounted for, those not assigned to dropping cyanid having left the building. Starting on the top floor, begin dropping the cyanid carefully, though quickly, into the generators, starting at the jars most distant from the exit and working rapidly toward the exit. This requires quick, cool-headed action. If a charge of cyanid is overlooked never go back to drop it; let it go—your safety comes first. When the last charge has been dropped leave the floor, closing the door behind, and repeat the operation on each successive lower floor.

When the person in charge feels that it is not wise to attempt to drop all charges of cyanid by hand because of difficulties in the way of retreat the *stringing method should be employed*. Novices often resort to this method, though experienced fumigators do not, except in difficult situations. Where floors are so crowded with machinery that a hasty exit can not be made, or in dropping charges in the basement where one must run upstairs to the first floor before reaching the exterior the use of the stringing method will eliminate danger. This method consists in passing strong cord through conveniently arranged screw-eyes, each string finally passing from a central point at the exit to and through a screw-eye in the ceiling, so that it will hang directly over the spot where the generator is to be placed. (See figs. 12, 13, and 14, 4.) The strings should be so arranged that they may all be lowered into the jars by releasing one main string. This may be done by carrying the strings leading to each jar through screw-eyes in the ceiling or wall to one stout cord at the exit, as illustrated in figure 12. After the strings have



FIG. 1. GENERATOR TOO CLOSE TO BAGS OF FLOUR.

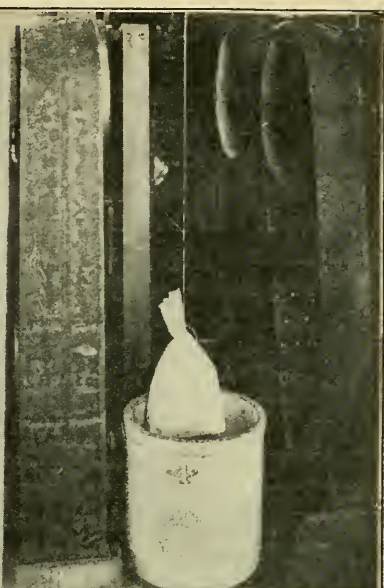


FIG. 2. GENERATOR TOO CLOSE TO BELTS AND BAG TOO LOW.



FIG. 3. GENERATOR TOO CLOSE TO BELTS AND BAG TOO HIGH.

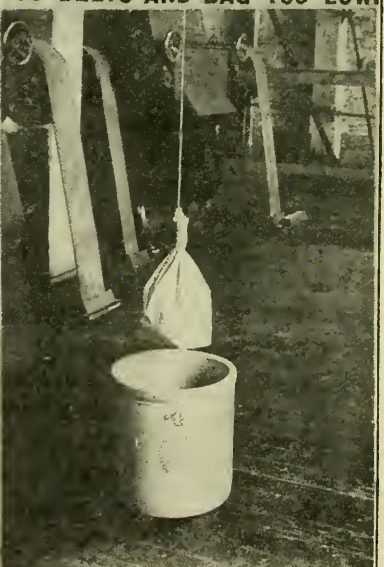


FIG. 4. CORRECT PLACING OF GENERATOR AND BAG.

FIG. 14.—The correct and incorrect placing of generators and bags of cyanid for hydrocyanic-acid gas fumigation. (Dean.)

been arranged, the generators should be placed and the water and acid added. Each generator should then be moved at least 2 feet away from where the cyanid will be suspended. Men should then go through the mill, tying firmly the sacks of cyanid to the strings, so that they will hang suspended about 2 or 3 inches above the tops of the generators. This done, the generators are placed beneath the suspended sacks. All persons should then leave the building. One man can now pass from the top to the lower floors lowering the cyanid into the generators by the simple manipulation of the central cord at the exit of each floor. The basement charge should, of course, be lowered last, and preferably by means of a cord running to the outside mill door or to the outside through some slight opening about a window.

CLOSING BUILDINGS AND GUARDING DOORS.

After the last charge has been set off and the last person has left the building, the door or doors used as exits should be locked. If such doors do not fit tightly, it will pay to paste strips of paper about their edges. Guards should be placed about the building in such a manner as to prevent persons entering the building. Guards should not stand where they can smell any amount of escaping gas. There should be several guards who keep in touch with one another, especially during the first one or two hours after the generation of gas.

TIME TO FUMIGATE AND LENGTH OF EXPOSURE.

Fumigate only during calm weather. During high winds the gas is carried to one side of the room or building and, unless the building is very tight, it is dissipated more quickly. Experiments have proved that insects are not active at temperatures lower than 50° to 60° F. and are not then so easily killed by the gas. Best results follow fumigations when the temperature is 70° F. or above. Everything for fumigation should be in readiness before dark. When possible the best time to fumigate is from Saturday afternoon to Sunday evening or Monday morning. At this time fewer people are about. The buildings should be allowed to remain closed for fumigation not less than 12 to 18 hours, though exposures of from 24 to 36 hours, when the building is tight and time is not an important factor, may effect a better killing of pests.

VENTILATION.

Several hours should elapse after a mill has been opened for ventilation before laborers are allowed to enter for regular work. The doors and the windows should be opened from without, according to provision made before fumigation. In opening windows and doors, open first those on the side of the building opposite to the

direction from which the wind is coming. After the preliminary ventilation has been in progress for one or two hours, it is safe for an operator to enter and open all windows and doors, but he should not remain in the building until it has been thoroughly aired. Specific directions as to the length of time for ventilation can not be given to meet all cases. Much depends upon the movement of air currents, the humidity of the air, and the rate of gas leaking from the building during the hours of fumigation. To be absolutely safe, buildings should be ventilated until there is no odor of gas before persons are allowed to resume their work. Men accustomed to fumigate soon acquire from experience knowledge which governs their action in remaining in buildings during the period of ventilation.

PROCEDURE AFTER VENTILATION.

After the mill has been ventilated thoroughly an operator should tour the building and make certain that no charge of cyanid was overlooked in the dropping or that no charge failed to be lowered into the generators if the stringing method was used. Any such charges should be removed from the building and placed with the stock of unused cyanid. Laborers should now be sent through the building to remove the generators, dumping their contents into a sewer or into a hole dug in the ground and giving the generators a thorough washing. If the chemical action has been complete, the residue in the jars after fumigation may not be particularly poisonous, yet it is acid, and will burn clothing and skin, and should be handled with care by reliable men. Men should be warned against deliberately inhaling any fumes that may be given off by the residue, either while they are removing the generators or emptying them. Generators that begin to bubble when disturbed should be avoided until the bubbling has ceased. When the residue has been absorbed, after it has been poured in the hole in the ground, the soil should be replaced.

EFFICIENCY OF FUMIGATION.

Experiments prove that in an air-tight chamber hydrocyanic-acid gas will penetrate in killing concentrations to a depth of 3 inches, but in mill fumigation the gas does not penetrate flour and mill products much beyond 1 inch, and often, particularly near the floor, not even that far. Not all mill pests are equally affected by the gas. In a mill infested by the Mediterranean flour moth hydrocyanic-acid gas is a very effective treatment. All stages of the moth, including the egg, if not covered with more than 1 inch of flour, are killed, but upon the several stages of the flour beetles, "bran bugs," and the cadelle the gas treatment is of less value. Many of these pests hide in places

inaccessible to the gas and escape treatment only to restock the mill later and offset the large numbers of their species killed during the fumigation.

FREQUENCY OF FUMIGATION.

Most millers who fumigate with hydrocyanic-acid gas apply the treatment once a year. Certain millers fumigate in the spring, give a second fumigation during midsummer, and a third during early fall. A more effective plan is to give two fumigations in July or August within three or four weeks of each other. Of the different stages of the moth, the egg stage is the most difficult to kill, and a certain number of eggs usually escape the first fumigation. If, then, a second fumigation is applied three to four weeks after the first, it will catch the worms that hatch from the eggs unaffected by the first fumigation, when they are in a stage easily killed by the gas; at that time they have not had an opportunity to develop into adult moths and lay more eggs. Fumigation is advocated only for the warm summer months.

EFFECTS OF HYDROCYANIC-ACID GAS UPON FLOUR.

Experiments conducted at the Kansas Agricultural Experiment Station, results of which are published in Bulletin No. 178 of that station, included fumigations of four grades of soft winter-wheat flour, consisting of a patent, a straight, a clear, and a low grade, and of three grades of hard winter wheat flour, consisting of a patent, a straight, and a low grade. Samples were fumigated at the maximum strength recommended for flour-mill fumigation, viz, 1 pound of cyanid to each 1,000 cubic feet of space. Flour was exposed to a temperature of 90° F in a tight chamber kept at constant temperature for a period of 12 hours. Dean, of Kansas, concludes:

It is only in the careful measurements employed in the test that any difference between the fumigated and the unfumigated flour is apparent at all. The only notable difference appears in the maximum volume of the dough in the test made immediately after fumigation, but not after thirty days. The finished loaf shows no deleterious effect from fumigation in any of the tests.

CONTROL BY HEAT.

It has been stated that fumigation with hydrocyanic-acid gas, effective as it is in controlling the Mediterranean flour moth in mills, does not control so satisfactorily the several stages of the flour beetles (*Tribolium confusum* Duv. and *T. ferrugineum* Fab.), the "bran bug" (*Laemophloeus minutus* Oliv.), the cadelle (*Tenebroides mauritanicus* L.), and the sawtoothed grain beetle (*Silvanus surinamensis* L.) These insects are naturally more resistant to the effect of gas, and secrete themselves in large numbers in cracks and accumu-

lations of fine stocks inaccessible to any gas. The flour beetles and the cadelle, the larval stages of which cause much trouble in flour, are in practically every flour mill in the country, except where remedial measures are successfully practiced. Inspection of ports in this country and in Europe through which the flour from many American mills is handled, either for domestic or for foreign trade, indicates that these insects just mentioned, which can not be controlled so satisfactorily by fumigation, are causing serious trouble, and that the large majority of the infestations originate at the mills.

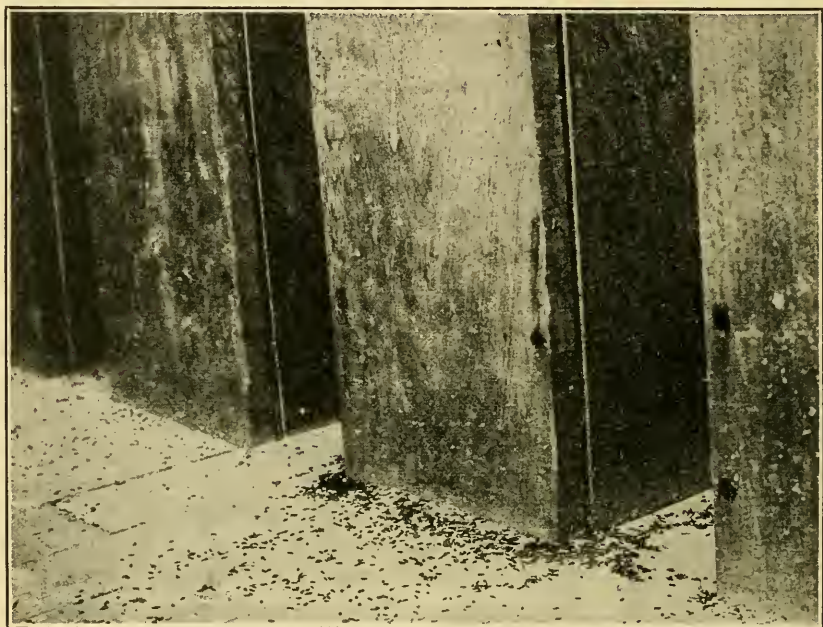


FIG. 15.—Photograph of elevator legs after application of the heat method of control. Note the large number of flour beetles which, on feeling the heat, have crawled out of the cracks of the wooden elevator legs and died upon the mill floor.

The most practical and effective method known to control all classes of mill-infesting insects is the application of high temperatures. (Fig. 15.)

Heat has been recognized as a control agent for many years in this country and in Europe. But its effectiveness as a control measure in flour mills was first demonstrated by professional experimental investigation by Prof. George A. Dean in several Kansas mills during the period 1910–1913.⁴ So successful were Dean's demonstrations that the heat method has been tested by the Federal Bureau of Entomology and by several State entomologists with the result that mills in

⁴DEAN, GEORGE A., MILL AND STORED-GRAIN INSECTS. KANS. State Exp. Sta. Bul. 189, p. 139–236, 56 figs., 6 pl., July, 1913.

Kansas, Ohio, Nebraska, Illinois, Indiana, Iowa, southern Canada, Virginia, and elsewhere are equipped for and are using the heat method. The result of all this work is that to-day the heat method is recognized as the most effective, practical, and inexpensive of all treatments, and has the added advantage of being absolutely safe. The greatest expense is the original installation of radiating surface. Yet this expense is offset by the greater cheapness of the heat method as compared with any other effective control measure. Goodwin,⁴ an experimenter in Ohio, claimed in 1912 that for a mill of average size, forced to apply remedial measures, the cost of steam piping necessary to obtain killing temperatures was offset within five years by the saving due to the cheapness of the heat method.

HEAT APPLIED MOST EFFECTIVELY IN SUMMER.

It is advised that heat be applied during the summer months in order that the normally high temperatures then obtaining may be turned to the advantage of the miller. It is much easier to raise the temperature of a mill to the killing point when the outdoor temperature is 85° F. or above. It takes less fuel and less radiation surface and saves time. Take advantage of summer heat. Heat only in quiet weather; it is impossible to get uniformly good results during windy weather.

DEGREE OF HEAT NECESSARY.

A temperature of 118° F. to 125° F. in all parts of the mill is sufficient to kill mill pests. To obtain these killing temperatures in the least exposed parts, it is necessary to heat other portions to a still higher temperature unless greater care than usual is taken to distribute radiation surfaces according to the situation. For temperatures secured in various parts of mills heated experimentally with equipments already installed, see data in Tables I to XII.

USE OF STEAM HEAT.

Steam heat is the most satisfactory heat for raising mill temperatures to the killing point. A pressure of 25 to 50 pounds is recommended.

AMOUNT OF RADIATION REQUIRED.

The number of square feet of radiation required to heat a given number of cubic feet of space depends upon the number of doors and windows in a building and upon the general tightness of the structure. Because these factors vary so greatly in mills, a definite recommendation for amount of radiation surface can not be given. The engi-

⁴ GOODWIN, W. H., FLOUR MILL FUMIGATION. Bul. Ohio Agr. Exp. Sta., no. 234, p. 184, January, 1912.

neer of each establishment, aided by one or two experimental heatings, will be able to increase or reduce the radiation surface in various parts of the mill until provision is made for securing sufficiently high temperatures. One square foot of radiation is usually sufficient to heat from 50 to 100 cubic feet of space. A mill with sufficient radiation to heat it during winter to 70° F. without the heat of the running machinery can be heated readily in summer to 120° F. or 125° F. Dean suggests for a five-story building 1 square foot of radiation to each 50, 60, 75, 90, and 110 cubic feet of space for the first, second, third, fourth, and fifth floors, respectively; and in a mill of four floors, 1 square foot of radiation to each 50, 60, 75, and 100 cubic feet of space for the first, second, third, and fourth floors, respectively. The amount of radiation surface per linear foot and the linear feet of pipe per square foot of radiation surface for pipes of varying sizes are as follows:

Size of pipe, in inches.	Radiation surface per linear foot.	Linear feet of pipe per square foot of radiation surface.
1.....	0.346	2.9
1½.....	.434	2.3
1½.....	.494	2.0
2.....	.622	1.6
2½.....	.753	1.3

If steam pipe is used for radiation the 1½-inch or 1½-inch size is recommended as most practical.

HEAT DOES NOT INJURE EQUIPMENT.

Heating mills as recommended for the control of mill pests will not injure the mill structure or equipment. In the many heatings on record no injury has occurred to belting or machinery, or, by checking, to elevator legs, woodwork of bolters, and purifiers. Mills have been heated to as high as 150° F. for 30 hours without injury to any part.

Objection made that insurance companies will not permit the heat method of control is without foundation. Mr. William Reed, as secretary of the Mutual Fire Protection Bureau, representing eight of the principal millers' insurance companies, in a notice to all policy holders stated, "We propose to advocate the heating system for effective fumigation against the Mediterranean flour moth, weevil, and all other mill and grain infesting insects."

FLOUR NOT AFFECTED BY HEAT METHOD.

Results of baking tests made of patent hard-wheat flour, a low-grade hard-wheat flour, and a pancake flour have proved conclu-

sively that the heat method, even at several degrees of temperature higher than recommended for mill treatment, has no injurious effect upon the baking qualities of the flour. A low hard-grade wheat flour was subjected to a temperature of 140° F. for nine hours on three successive occasions (the second and third heatings occurring two and six weeks after the first heating), and a pancake flour was subjected to a temperature of 130° F. for 48 hours without injurious results.

EFFECT OF HEATING UPON MILL HUMIDITY.

Heating to kill mill insects greatly reduces the humidity in the mill. Insects die more quickly in a dry heat than in a moist heat. The relative humidity on the second floor of a mill at 10 a. m., when the heat was turned on, was 93 per cent; by 12 m. it had fallen to 40 per cent, and by 5.30 p. m. to 27 per cent. In a second mill the relative humidity at 6 a. m., when the heat was turned on, was recorded by a hygrograph as 72 per cent; during the first few hours following there was a rapid decrease to less than 40 per cent, and during the afternoon and throughout the night there was a still further decrease to 12 per cent.

IMPORTANT POINTS TO BE CONSIDERED IN THE SUCCESSFUL HEATING OF A MILL.

1. Steam pipes should be located near floor and arranged to give equal distribution of heat.
2. Provide water trap for drawing off accumulation of water in pipes.
3. Lower floors and floors with heavy machinery should have more radiating surface in proportion to cubic feet of space than upper floors and floors with light machinery.
4. Mill will heat more rapidly with a steam pressure of 25 to 50 pounds.
5. To take advantage of heat in machinery begin heating mill immediately after shutdown.
6. Stairways and elevator shafts should be closed, so as to make separate units of each floor.
7. Thermometers should be placed at different points on each floor that temperatures may be readily ascertained.
8. Time must be taken to reach desired temperatures.
9. A temperature of 118° F. to 125° F. is sufficient for any part of mill.
10. This temperature should be maintained for several hours to allow heat to penetrate all infested parts.
11. Do not attempt to heat on a windy, cold, or rainy day.

12. By beginning the heat process directly after shutting down mill Saturday afternoon and continuing until Sunday night or early Monday, there is no loss in producing hours.

EXPERIMENTAL DATA ON HEAT FUMIGATION.

The following temperatures and results were secured in experimental work by Dean (mills 1 to 4) and by Goodwin⁵ (mill 5).

MILL No. 1.

Brick building; day (July 7-8, 1912) calm, partly cloudy; outdoor maximum temperature 91° F., outdoor minimum temperature 73° F. Heating system, steam pipes along walls, except in space beneath first floor where radiators are used. Steam pressure of about 20 pounds maintained during experiment. Capacity of mills, 600 barrels.

ON FIRST AND SECOND FLOORS.

Location and reading of thermometers.—The thermometers were located on these floors as follows: No. 1, in 2 inches of flour in elevator boot on floor, 8 feet beneath steam pipes; No. 2, hanging in middle of room, 5 feet high, 15 feet from steam pipes; No. 3, in 2 inches of flour in elevator boot on floor, 12 feet from steam pipes; No. 4, hanging in the open, 4 feet high, 15 feet from steam pipes; No. 5, between the rolls in a roll, 11 feet from steam pipes; No. 6, hanging in the open, 6 feet high, near roll machinery.

TABLE I.—Data showing rise in temperatures on first and second floors.

Time of day.	First floor: Capacity, 28,728 cubic feet; radiation, 525 square feet.		Second floor: Capacity, 28,728 cubic feet; radiation, 560 square feet.			
	Thermometer—					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
	° F.	° F.	° F.	° F.	° F.	° F.
July 7, 1912:						
10.30 a. m.	83	90	86	98	97	99
11.30 a. m.	83	94	88	105	97	106
12.30 p. m.	84	98	91	110	98	111
2.30 p. m.	88	104	96	117	100	118
3.30 p. m.	90	106	100	120	102	121
4.30 p. m.	93	107	102	123	104	123
5.30 p. m.	94	110	103	125	105	125
7 p. m.	95	110	107	127	108	127
8.30 p. m.	97	113	108	129	109	129
9.30 p. m.	98	115	108	130	111	129
July 8, 1912:						
9 a. m.	100	122	116	140	122	140
11 a. m.	106	124	117	142	125	142
12 m.	106	125	118	144	126	144
2 p. m.	106	128	118	144	127	144
4 p. m.	107	129	120	147	129	147
5.30 p. m.	108	129	121	146	131	145

ON THIRD AND FOURTH FLOORS.

Location and reading of thermometers.—Thermometers were located on these floors as follows: No. 1, hanging in the open, 5 feet high, 15 feet from steam

⁵ Op. cit.

pipes; No. 2, in flour in a conveyor near floor, 12 feet from steam pipes; No. 3, in flour in conveyor, 6 feet high, 15 feet from steam pipes; No. 4, hanging in the open, 5 feet high, 12 feet from steam pipes; No. 5, in flour, in a conveyor near floor, 12 feet from steam pipes; No. 6, in flour, in a conveyor near floor, 12 feet from steam pipes.

TABLE II.—*Data showing rise in temperatures on third and fourth floors.*

Time of day.	Third floor: Capacity, 31,122 cubic feet; radiation, 460 square feet.		Fourth floor: Capacity, 43,092 cubic feet; radiation, 400 square feet.			
	Thermometer.					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
July 7, 1912:	° F.	° F.	° F.	° F.	° F.	° F.
10.30 a. m.	95	85	89	96	88	88
11.30 a. m.	100	88	91	100	90	90
12.30 p. m.	105	91	95	105	92	91
2.30 p. m.	114	100	102	114	99	97
3.30 p. m.	116	102	103	116	101	99
4.30 p. m.	119	105	107	118	103	101
5.30 p. m.	122	107	108	119	106	103
7 p. m.	124	111	111	120	109	106
8.30 p. m.	126	113	113	121	111	109
9.30 p. m.	127	114	114	122	112	110
July 8, 1912:						
9 a. m.	133	126	125	127	118	117
11 a. m.	138	127	125	129	119	118
12 m.	139	127	126	132	120	119
2 p. m.	141	128	128	133	121	120
4 p. m.	143	128	131	138	124	122
5.30 p. m.	145	129	131	138	124	122

RESULTS OF HEATING MILL NO. 1.

One hundred per cent of all insects were killed on the second, third, and fourth floors. All insects were killed on the first floor, except those in elevator boots on the floor, where killing temperatures were not secured except directly over the radiators in the space beneath the floor.

MILL NO. 2.

Brick building; day (July 21, 1912) partly cloudy and calm; maximum outdoor temperature 97° F.; minimum outdoor temperature 74° F. Heating system, steam pipes along wall and a few radiators. Steam pressure of about 100 pounds maintained during heating. Capacity of mill, 1,000 barrels.

BASEMENT AND FIRST FLOOR.

Location and reading of thermometers.—No. 1, in flour in an elevator boot resting on floor, 5 feet from steam pipes; No. 2, hanging in the open, 6 feet high, 10 feet from steam pipes; No. 3, in flour in an elevator boot resting on floor, 15 feet from steam pipes; No. 4, in flour in an elevator boot resting on floor, 10 feet from steam pipes; No. 5, hanging in the open, 6 feet high, 15 feet from steam pipes; No. 6, in flour in a roll, 20 feet from steam pipes; No. 7, in flour in a roll in the cleaning room, 5 feet from a radiator.

TABLE III.—Data showing rise in temperatures in basement and on first floor.

Time of day.	Basement: Capacity, 33,790 cubic feet; radiation, 1,020 square feet				First floor: Capacity, 40,040 cubic feet; radiation, 780 square feet.		
	Thermometer—						
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
July 21, 1912:	° F.	° F.	° F.	° F.	° F.	° F.	° F.
8 a. m.	96	128	98	98	130	121	97
10 a. m.	97	134	104	98	138	123	100
12 m.	100	136	105	98	140	123	102
2 p. m.	102	136	107	102	140	124	108
4 p. m.	104	38	108	106	142	125	111
6 p. m.	103	140	109	109	143	127	113
8 p. m.	103	143	109	109			
10.30 p. m.	102	145	113	109	146	131	119

SECOND AND THIRD FLOORS.

Location and reading of thermometers.—No. 1, hanging in the open, 6 feet high, 15 feet from steam pipes; No. 2, in flour in bottom of an elevator boot, 15 feet from steam pipes; No. 3, in flour on bolting cloth in a reel, 12 feet from radiation (cleaning room); No. 4, hanging in the open, 5 feet high, 12 feet from steam pipes; No. 5, in flour in a conveyor, 14 feet from steam pipes; No. 6, hanging in the open, 5 feet high, 10 feet from radiator (cleaning room).

TABLE IV.—Data showing rise in temperature on second and third floors.

Time of day.	Second floor: Capacity, 43,120 cubic feet; radiation, 800 square feet.			Third floor: Capacity, 43,120 cubic feet; radiation, 900 square feet.		
	Thermometer—					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
	° F.	° F.	° F.	° F.	° F.	° F.
July 21, 1912:						
8 a. m.....	137	112	110	120	108	116
10 a. m.....	144	119	113	126	114	121
12 m.....	147	122	115	131	116	125
2 p. m.....	151	127	121	136	120	130
4 p. m.....	153	130	124	138	123	132
6 p. m.....	153	128	126	139	124	134
8 p. m.....	154	128	128	141	127	136
10.30 p. m.....	156	130	129	142	129	138

RESULTS OF HEATING MILL NO. 2.

One hundred per cent of the insects were killed everywhere except in elevator boots resting on the concrete floor in the basement.

MILL NO. 3.

Brick building; day (July 27–28, 1912) calm and partly cloudy; outdoor maximum temperature 105° F.; outdoor minimum temperature 73° F.; heating system, steam pipes along wall; steam pressure of about 100 pounds maintained during heating. Capacity of mill, 1,000 barrels.

BASEMENT, FIRST, AND SECOND FLOORS.

Location and reading of thermometers.—No. 1, hanging in the open, 5 feet high; No. 2, in flour in an elevator boot resting on floor; No. 3, in flour in an elevator boot resting on floor; No. 4, in some bran in a roll, 12 feet from steam pipes; No. 5, hanging in the open, 5 feet high, 10 feet from steam pipes; No. 6, in flour in an elevator boot resting on floor; No. 7, hanging in the open, 5 feet high, 15 feet from steam pipes; No. 8, in flour in a conveyor, 20 feet from steam pipes; No. 9, in 4 inches of flour near floor, 8 feet from steam pipes.

TABLE V.—Data showing rises in temperatures in basement and on first and second floors.

Time of day.	B a s e m e n t: Capacity, 23,199 cubic feet; radiation, 260 square feet.			First floor: Capacity, 29,526 cubic feet; radiation, 210 square feet.			Second floor: Capacity, 27,417 cubic feet; radiation, 168 square feet.		
	Thermometer—								
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.
July 27-28:	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
9.30 p. m.	113	104	102	110	118	105	117	108	109
11.30 p. m.	112	102	102	113	121	107	120	111	112
July 28:									
6.30 a. m.	109	96	100	116	123	110	126	114	120
7.30 a. m.	110	99	99	118	124	110	126	116	120
9.30 a. m.	118	108	110	120	128	113	130	117	121
11.30 a. m.	122	109	109	122	129	114	131	119	124
12.30 p. m.	122	110	110	123	130	115	132	131	134
2.30 p. m.	124	113	113	124	131	116	133	122	126
4.30 p. m.	128	114	115	126	134	119	136	125	128
5.30 p. m.	129	115	115	127	135	120	137	127	128
7.30 p. m.	130	119	118	130	137	123	138	128	130
9.30 p. m.	130	117	117	130	137	123	138	128	130
11 p. m.	130	118	118						
July 29:									
1 a. m.	134	120	120						
3 a. m.	136	122	122						
4.30 a. m.	136	122	122						

THIRD FLOOR AND DECK.

Location and reading of thermometers.—No. 1, in flour in a conveyor near the floor, 20 feet from steam pipes; No. 2, hanging in the open, 5 feet high, 12 feet from steam pipes; No. 3, in a pile of flour on the floor, 10 feet from steam pipes; No. 4, hanging in the open, 5 feet high; No. 5, in refuse flour on the base of a dust collector near the floor; No. 6, in flour 3 feet from the floor.

TABLE VI.—Data showing rise in temperatures on third floor and deck.

Time of day.	Third floor and deck: Capacity, 45,343 cubic feet, including deck; radiation, 326 square feet; radiation, deck, none.					
	Thermometer—					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
July 27-28:	° F.	° F.	° F.	° F.	° F.	° F.
9.30 p. m.	111	120	111	123	113	115
11.30 p. m.	113	122	113	124	115	116
6.30 a. m.	118	128	119	130	120	122
7.30 a. m.	119	130	120	131	122	124
9.30 a. m.	122	132	122	134	125	126
11.30 a. m.	124	136	124	138	127	129
12.30 p. m.	125	137	125	138	128	130
2.30 p. m.	128	139	128	141	133	134
4.30 p. m.	129	141	129	143	133	136
5.30 p. m.	130	142	130	144	134	137
7.30 p. m.	132	142	132	144	136	138
9.30 p. m.	132	141	131	143	136	138

RESULTS OF HEATING MILL NO. 3.

One hundred per cent of insects were killed on the first to deck floors. In the basement 90 per cent were killed; the steam-pipe exhaust opened into a pit beneath the basement floor and this allowed the escaping steam to enter the basement and keep the air moist.

MILL No. 4.

Frame building; day (July 28, 1912) partly cloudy with light breeze; outdoor maximum temperature 95° F.; outdoor minimum temperature 72° F. Heating system, steam pipes along wall, steam pressure of about 80 pounds maintained during heating. Capacity, 1,000 barrels.

FIRST FLOOR.

Location and reading of thermometers.—No. 1, hanging in the open, 5 feet high, 15 feet from steam pipes; No. 2, hanging in the open, 5 feet high, 18 feet from steam pipes; No. 3, resting on a roll in a roller, 12 feet from steam pipe; No. 4, in 2 inches of flour near floor, 5 feet from steam pipes; No. 5, in flour in a conveyor near floor, 20 feet from steam pipes; No. 6, hanging in the open 6 feet high, 20 feet from steam pipes.

TABLE VII.—Data showing rise in temperature on first floor.

Time of day.	First floor: Capacity, 34,790 cubic feet; radiation 262 square feet.					
	Thermometers—					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
July 28, 1912:	° F.	° F.	° F.	° F.	° F.	° F.
8 a. m.	98	96	105	90	96	110
10 a. m.	104	101	106	94	104	113
12 m.	110	106	108	97	108	117
2 p. m.	114	111	109	102	105	120
4 p. m.	118	115	110	107	108	122
6 p. m.	120	116	110	110	110	123
8 p. m.	121	117	112	113	112	126
9 p. m.	121	118	113	114	112	126
9.30 p. m.	121	118	113	114	112	126

SECOND FLOOR.

Location and reading of thermometers.—No. 1, hanging in the open, 5 feet high, 22 feet from steam pipes; No. 2, hanging in the open, 5 feet high, 18 feet from steam pipes; No. 3, in 3 inches of bran near floor, 5 feet from steam pipes; No. 4, in flour in an elevator boot resting on floor, 17 feet from steam pipes; No. 5, in an oven in a laboratory, 5 feet high and 3 feet from steam pipes; No. 6, in flour in an elevator boot resting on floor, 30 feet from steam pipes.

TABLE VIII.—Data showing rise in temperature on second floor.

Time of day.	Second floor: Capacity, 38,269 cubic feet; radiation, 190 square feet.					
	Thermometer—					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
July 28, 1912:	° F.	° F.	° F.	° F.	° F.	° F.
8 a. m.	98	94	93	92	120	94
10 a. m.	102	100	93	94	128	97
12 m.	108	104	95	99	134	100
2 p. m.	114	112	99	104	139	106
4 p. m.	118	115	103	107	142	106
6 p. m.	120	118	106	108	143	108
8 p. m.	122	118	110	110	144	110
9.30 p. m.	122	119	110	112	144	110

THIRD FLOOR.

Location and reading of thermometers.—No. 1, hanging in the open, 5 feet high, 22 feet from steam pipes; No. 2, hanging in the open, 5 feet high, 20 feet from steam pipes; No. 3, in flour in conveyor, 6 feet high, 8 feet from steam pipes; No. 4, in flour in a purifier, 4 feet high, 13 feet from steam pipes; No. 5, in flour in an elevator boot resting on floor, 4 feet from steam pipes; No. 6, in flour in a conveyor near floor, 11 feet from steam pipes.

TABLE IX.—Data showing rise in temperatures on third floor.

Time of day.	Third floor: Capacity, 49,375 cubic feet; radiation, 267 square feet.					
	Thermometer—					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
July 28, 1912:	° F.	° F.	° F.	° F.	° F.	° F.
8 a. m.	98	95	94	96	96	102
10 a. m.	104	101	100	98	96	102
12 m.	109	106	104	104	100	99
2 p. m.	115	112	108	108	104	103
4 p. m.	120	117	112	112	108	108
6 p. m.	124	121	116	116	112	112
8 p. m.	126	123	119	118	114	115
9.30 p. m.	127	124	120	122	116	114

FOURTH FLOOR AND DECK.

Location and reading of thermometers.—No. 1, hanging in the open, 5 feet high, 26 feet from steam pipes; No. 2, hanging in the open, 5 feet high, 28 feet from steam pipes; No. 3, in flour in an elevator boot, 6 inches from floor, 24 feet from steam pipes; No. 4, in flour in a conveyor near floor, 13 feet from steam pipes; No. 5, in flour in a conveyor near floor, 22 feet from steam pipes; No. 6, hanging in the open, 5 feet from floor; No. 7, in flour in a conveyor near floor.

TABLE X.—Data showing rise in temperatures on fourth floor and deck.

Time of day.	Fourth floor and deck: Capacity, 69,580 cubic feet, including deck; radiation, 310 square feet; radiation, deck, none.						
	Thermometer—					Deck thermometer—	
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
July 28, 1912:	° F.	° F.	° F.	° F.	° F.	° F.	° F.
9 a. m.	101	98	93	94	97	104	100
10 a. m.	103	100	95	96	92	106	99
12 m.	110	107	102	100	98	114	112
2 p. m.	116	114	107	102	100	122	113
4 p. m.	122	120	113	106	105	126	118
6 p. m.	126	123	116	110	109	128	123
8 p. m.	126	123	118	115	113	127	125
9.30 p. m.	127	124	118	114	113	127	126

RESULTS OF HEATING MILL NO. 4.

One hundred per cent of the insects were killed on the third, fourth, and deck floors, 95 to 100 per cent were killed on the second, and 90 to 95 per cent were killed on the first floor.

MILL No. 5.

Frame structure, not tightly constructed and with many small openings where lap-siding boards had sprung apart or warped. There are also small openings about doors. Building too loosely constructed for satisfactory fumigation with gas. Day (July 10-11, 1911) calm except for slight breeze blowing from southwest after 9 a. m. July 11, which somewhat affected temperatures on that side of building. Mill equipped with radiators for heating by steam during winter. Outdoor maximum temperature 95° F. No mention made of steam pressure or minimum outdoor temperature.

FIRST AND SECOND FLOORS.

Location and reading of thermometers.—No. 1, near airshaft; No. 2, set 5 inches deep in flour; No. 3, in boot of elevator; No. 4, three feet from floor; No. 5, on inside of outer wall; No. 6, near floor in elevator leg; No. 7, on support post; No. 8, on outside wall; No. 9, in a roll.

TABLE XI.—Data showing rise in temperatures on first and second floors.

Time of day.	First floor.					Second floor.			
	Thermometer—								
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 1.	No. 2.	No. 3.	No. 4.
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
7.30 p. m.	90	86	100	102	95	107	102	101	107
9.30 p. m.	94	91	102	124	101	120	115	109	119
11.30 p. m.	95	95	106	127	103	122	117	116	122
6 a. m.	96	103	108	131	108	128	124	118	129
8 a. m.	99	104	112	134	111	130	127	120	131
10 a. m.	104	107	113	141	115	135	132	125	137
12 m.	106	109	114	141	116	137	133	126	137
2 p. m.	106	110	115	141	116	137	134	124	138
3 p. m.	107	111	116	141	118	.....	.....	.....	.....

THIRD FLOOR AND DECK.

Location and reading of thermometers.—No. 1, in conveyor, in 3 inches of flour; No. 2, in elevator leg; No. 3, near outside wall; No. 4, in bolter; No. 5, on a post on the deck built on third floor.

TABLE XII.—Data showing rise in temperatures on third floor and deck.

Time of day.	Thermometer—				
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
	° F.	° F.	° F.	° F.	° F.
7.30 p. m.	93	104	102	102	104
9.30 p. m.	104	113	113	116	113
11.30 p. m.	107	118	116	121	116
6 a. m.	118	125	125	129	129
8 a. m.	119	129	129	133	137
10 a. m.	122	134	138	138	140
12 m.	124	135	136	139	142
2 p. m.	127	136	136	139	142

RESULTS OF HEATING MILL NO. 5.

All insects were killed on the second and third floors. Dead beetles and larvæ could be found beneath 3 inches of flour. All insects were killed on the first floor except near air shaft (thermometer No. 1) and those buried 5 inches in flour (thermometer No. 2).

CONTROL BY FREEZING.

If an infested mill is so equipped that it can be opened to low outdoor temperatures without injury to equipment, freezing is an inexpensive and valuable remedy for the flour moth. Turning off all heat and opening the mill to a temperature of zero or lower for from 3 to 10 nights continuously, or at intervals, has often proved effective in destroying the moth in its different stages. Mills in the northern United States and in Canada, where temperatures of 20 to 30 degrees below zero (Fahrenheit) are often experienced, have used this method of control with good results. Mills located farther south where freezing temperatures do not run so low or prevail continuously for any length of time have had little or no benefit from attempts to utilize cold weather.

CONTROL BY SMUDGES.

Control by means of smudges in the form of sulphur or tobacco fumes, etc., is depended upon rather extensively in many mills to reduce flour-moth injury. With smudges one can only expect to reduce the flour moth temporarily by killing the adult moths and certain of the immature stages. The fumes generated are not strong enough to kill as do hydrocyanic-acid gas fumigation and high temperatures. In rambling, loosely constructed buildings, where control by heat and hydrocyanic-acid gas is not practical, smudges, coupled with constant cleaning, have their value. The moth miller or adult is the most easily killed of the different stages of the flour moth and is the form killed in largest proportions by smudges. Since each female moth is the potential parent of several hundred larvæ, one can appreciate the value of the persistent use of smudges. The chief drawback to dependence upon smudges is that they never completely exterminate the moth. Smudges, to accomplish satisfactory results, must be applied frequently, and are therefore costly in the long run. One thorough application of heat rids a mill of the flour moth for long periods if provision is made against reinfestation from without. Flying moths may be found as soon as one day after the application of a smudge.

CONCLUSION.

Control of insect pests in flour and cereal mills has become a very important feature of food conservation and of mill construction and operation. Losses caused by mill insects to mill owners and the ad-

vantages of modern mill construction are working hand in hand to bring about a constant change for the better. Putting into practice methods of control advocated in this bulletin will make it possible for milling concerns to place upon the market a product reasonably free from infestation. When insect sanitation is conscientiously applied, millers can state that blame often heaped upon them by brokers, retail grocers, and the public at large is due to one or more of several known conditions connected with warehousing and transportation, for the miller is in no way responsible.

There are a number of serious insect pests of flour mills. The long-established pests in American mills do not interfere noticeably with operation of mill machinery. With the spread from Europe to the United States of the Mediterranean flour moth (p. 2-5), millers were forced to consider insect sanitation. The danger in the flour moth, sometimes called the "gray plague of flour mills," does not lie so much in food values actually consumed as in the enormous quantities of silken threads spun by its larvæ in and about mill machinery. This webbing habit causes the flour in passing through the machinery to form in ever-increasing clumps or webbed masses, which sooner or later choke or clog the machinery, and necessitates extensive mill shutdowns for cleaning and application of control measures.

Experimental and practical demonstration work has proved the dependability of methods of control under certain conditions. These are fumigation with hydrocyanic-acid gas and the use of heat. Control by freezing (p. 39) is less satisfactory. Smudges, as compared with fumigation with hydrocyanic-acid gas or the application of high temperatures, have only a temporary value. Preventive measures, including cleanliness, are of the greatest value in reducing losses due to insects. Dependence upon natural control by parasites is not advocated. The heat method is recognized as the most effective, practical, and inexpensive of all treatments and has the added advantage of being absolutely safe. Where remedial measures must be applied in mills of moderate size, it has been estimated that the heat method is enough cheaper to pay in five years for the cost of the installation of enough radiation surface properly to heat the mill.

Neither fumigation with hydrocyanic-acid gas nor the use of high temperatures, as recommended for mill-insect sanitation, injures the mill building or equipment or affects the baking qualities of flour.

UNITED STATES DEPARTMENT OF AGRICULTURE



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L. O. HOWARD, Chief

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COTTON BOLL WEEVIL CONTROL BY THE USE OF POISON.¹

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PRINCIPLES GOVERNING POISONING OPERATION.

IT SHOULD BE UNDERSTOOD that in poisoning for boll-weevil control extermination is not attempted or secured. The result aimed at is a sufficient reduction of the weevil infestation to permit maturing a full crop of cotton. This is brought about by tak-

¹ The investigations upon which this bulletin is based were in a sense the outgrowth of the work of Mr. Wilmon Newell, who published, together with Mr. G. D. Smith, in 174542°—Bul. 875—20—1

ing advantage of a combination of factors. In the first place, the cotton plant has a peculiar habit of putting on much more fruit than it is able to mature. About 60 per cent of the squares which appear on the cotton plant fail to reach maturity as bolls, and are shed at some time during their development. This does not mean, however, that the cotton plant is shedding 60 per cent of its fruit throughout the season. This shedding is comparatively slight early in the season and increases rapidly as the plants develop until it reaches the point where all the new fruit which appears is shed. It has been found that up to a certain point the fruit shedding due to boll-weevil attack merely takes the place of this perfectly normal shedding which would be encountered even if the weevils were absent.

The present system of weevil poisoning is intended merely to keep the weevils controlled to such a degree that they will not be able to do more than offset the normal shedding of the cotton plants. This means, generally speaking, that the weevils are permitted to multiply unmolested until they have become sufficiently abundant to puncture more forms than would shed normally. Poisoning is then started and every effort is directed toward holding the infestation below this point of danger until the plants have had sufficient time to develop beyond weevil injury as many bolls as they will be able to mature. Then poisoning is stopped and the weevils are allowed to resume multiplication. Experience has shown that remarkably large increases in yield frequently result from a comparatively slight degree of control for a short time during this critical period. It has also been very definitely determined, however, that this effect is cumulative and can only be secured by starting the applications at the right time and repeating them at the correct time interval. This is the reason the writers urge everyone contemplating weevil poisoning to decide upon conducting the operation as thoroughly as recommended or not to attempt it at all.

Circular 33 of the Louisiana State Crop Pest Commission, an account of experiments in controlling the boll weevil by the application of powdered arsenate of lead which were conducted in Louisiana during 1908 and 1909.

The studies of the U. S. Department of Agriculture on the subject of cotton boll weevil poisoning were first described in Department Bulletin 731, July, 1918. The present bulletin gives the results of investigations carried on since that time. It is to be followed by a detailed bulletin giving descriptions of the various tests and studies which serve as a basis for the recommendations made. The latter will also include a discussion of the contributions to the subject which have been made by various investigators for many years. The work has been conducted under the general direction of Dr. W. D. Hunter. The development of dusting machinery has been under the direction of Elmer Johnson, of the Bureau of Public Roads. The following have contributed to field and laboratory studies: F. F. Bondy, H. W. Lee, T. F. McGehee, R. W. Moreland, L. Z. Naylor, M. C. Rodgers, E. S. Tucker, W. B. Williams, and M. T. Young. The practical field tests have been rendered possible only by the hearty cooperation of the following: Prof. J. W. Fox, general manager, Delta & Pine Land Co. of Mississippi, Scott, Miss.; Mr. Alex. Y. Scott, general manager, Charles Scott's Delta Plantations, Rosedale, Miss.; and Mr. George S. Yerger, general manager, Maxwell-Yerger Planting Co., Mound, La.

KIND OF POISON TO USE.

In the various studies which have been conducted by the writers, nearly every known type of arsenical has been tested, but the first generally successful results were secured from the use of an improved type of arsenate of lead. This was soon replaced by calcium arsenate, and this chemical remains the best which has been found for this purpose so far. Tests were conducted with both liquid and dry applications, and it was found that with the liquid spray a slight degree of control was secured, but not nearly enough to make the operation profitable.

POISON SPECIFICATIONS REQUIRED.

When calcium arsenate was first tested it was found that the material as then prepared was not safe for use on cotton plants, owing to the injury caused by burning of the foliage. This was due to the excessive amount of water-soluble arsenic present. It was found that it was possible to make calcium arsenate without this high percentage of soluble arsenic, and the type which is now recommended for this work is absolutely safe for use on plants. Not all calcium arsenate, however, is of this safe type. Anyone attempting this work should purchase the calcium arsenate on specifications describing its composition. The specifications advised are as follows:

Not less than 40 per cent arsenic pentoxid. Not more than 0.75 per cent water-soluble arsenic pentoxid. Density not less than 80 or more than 100 cubic inches per pound.

Calcium arsenate was almost unknown as an insecticide when these experiments were inaugurated, and its production had been attempted by only a few manufacturers. Recently, however, almost all insecticide manufacturers have undertaken its production. While its manufacture is comparatively simple, some experience is required to produce a thoroughly satisfactory material. Undoubtedly this difficulty will decrease rapidly as the manufacturers gain more experience in the production of calcium arsenate and the quality of the material becomes standardized, but for the present it is still advisable to make purchases only on the specifications recommended. If the total arsenic content is too low, the material is not sufficiently poisonous to control the weevil. If the proportion of water-soluble arsenic is too high, plant injury will be the result. Some lots of calcium arsenate have been found which killed the cotton plants within a few hours after application. It is also important to watch the density of the material very closely. If it is too heavy and runs much less than 80 cubic inches to the pound, it is not suitable for use in dry powdered form and will not produce the proper type of dust

cloud to cover the cotton plants thoroughly. Likewise, if the material is too light and runs much over 100 cubic inches per pound, it is blown away from the plants too rapidly by any light air currents.

SEND SAMPLES OF CALCIUM ARSENATE FOR ANALYSIS.

The best way to make sure of having the proper grade of calcium arsenate is to send a sample to the Delta Laboratory at Tallulah, La., for free analysis. This analytical service was started by the United States Department of Agriculture last season and if possible will be continued until the quality of calcium arsenate on the market becomes more uniform. Every cotton planter who purchases calcium arsenate for this work is invited to send in samples and he will be given an immediate report as to whether or not the material is satisfactory for use in cotton dusting. For this purpose it is advisable to take at least two or three samples from as many different packages. Probably the best plan is to sample 1 package in every 10 purchased. Half-pound samples should be taken from each and packed separately. The complete record of each sample should be packed with that sample, giving its full history, including name of manufacturer, when purchased, size and type of package, condition of material, analysis claimed by manufacturer, etc.

USE OF MIXTURES NOT RECOMMENDED.

The only chemical now recommended for boll-weevil poisoning consists of calcium arsenate which conforms to the specifications described. Attempts have been made to utilize various mixtures of arsenicals or dilutions of calcium arsenate. It is quite possible that some of these may prove satisfactory in the future, but with our present information it is advisable to adhere strictly to the use of calcium arsenate without the addition of any diluent whatever.

SUPPLY OF CALCIUM ARSENATE AND DUSTING MACHINERY AVAILABLE.

Prior to 1919 the production of calcium arsenate was so limited that it was difficult to secure a sufficient amount to conduct the experiments desired in this work. During 1919, however, interest in its production was stimulated to the point where probably 3,000,000 pounds were sold for cotton-dusting work. It appears that a fairly ample supply of calcium arsenate will be available for 1920. This is especially true in view of the probable shortage of dusting machinery. It has been found that successful results can not be secured unless special types of dusting machinery are utilized. These machines must be prepared for this particular purpose and their development has been considerably slower than that of the poison. At the present time the supply of machinery available is hardly sufficient to serve for the proper application of the poison already sold by the various manufacturers.

KEEPING QUALITIES OF CALCIUM ARSENATE.

Questions frequently are received as to whether or not calcium arsenate will deteriorate during long periods of storage. In some cases farmers purchased more than they could use during the past season and desired to hold over their surplus stock for use during the coming year. This is perfectly safe, as a properly made calcium arsenate should not deteriorate if stored in a reasonably dry place. Some lots have been kept at the Delta Laboratory for four years under normal storage conditions without the slightest deterioration. Moisture, however, even when it does not induce chemical deterioration, will cause calcium arsenate to cake so badly that it can not be utilized in the dusting machines.

EFFECT OF THE POISON ON MAN AND ANIMALS.

Questions are frequently asked regarding the effect of calcium arsenate on laborers and mules engaged in the poisoning operations. It is not nearly as dangerous as Paris green, as it does not have the caustic action characteristic of the latter. There is, however, a certain amount of danger attendant upon the use of any arsenical compound and reasonable precautions should be taken to protect the men and animals associated with it. Inhaling the dust should be avoided as far as possible. The most important precaution is that of personal cleanliness when using the material. The operators should be forced to bathe as soon as they complete the dusting work, and they should not be permitted to eat anything without at least washing their hands and face thoroughly. No injury to work stock has ever been experienced during operations, but it is safest to keep ordinary wire muzzles on all such animals in the poisoned fields.

The question of fall grazing of poisoned cotton fields is frequently raised. As a rule the last application of poison is made at least a month, and usually two or three months, before the cotton crop is harvested and the animals allowed to graze on the cotton fields. Even if no rains have occurred to wash the poison from the plants during this period, the amount of leaf shed has been so great that the foliage of the plant has probably been renewed several times and the plants utilized for grazing purposes are largely, if not entirely, new growth.

With regard to the danger to man involved in the use of calcium arsenate in the form of a dust cloud, it should be understood that arsenic may be taken into the body in three ways—by the mouth, by breathing, and by absorption through the skin. Ingestion or swallowing is the only manner which usually receives serious consideration, but in all probability it is the least important of the

three and can be avoided very easily by careful washing of the hands and face before eating or drinking.

Inhalation is a danger which is constantly present and is difficult to avoid except by the use of dust masks or some type of filtering arrangement which removes the dust from the air entering the mouth and nostrils.

Absorption undoubtedly is a very important means of taking arsenic into the human body. Even if extreme precautions are taken during dusting operations to avoid excessive direct contact with the poison supply, there is still a very considerable amount of poison dust settling all over the body from the air. This also has a decided tendency to adhere to the skin and "shed" water unless a strong lather is utilized, so a hasty rinsing in clear water should not be considered as a satisfactory means of removing the poison.

The danger of poisoning, although slight, should be considered. In the work conducted under the direction of the writers large quantities of calcium arsenate have been used by all sorts of laborers and generally with extreme carelessness. In spite of this, however, very few definite symptoms of even the slightest arsenical poisoning have been observed in connection with the field operations, and these few undoubtedly would have been avoided if proper precautions had been taken. Anyone using dry powdered calcium arsenate need not fear poisoning if he is reasonably cautious, but if any unexplained illness should develop during its use the possibility of poisoning should be borne in mind and a physician consulted. The preliminary symptoms of arsenical poisoning differ widely, but generally involve an intestinal and digestive disorder and are usually accompanied by some form of skin eruption.

An additional indirect danger to live stock should be considered. The cloud of poison frequently has a tendency to drift considerable distances. Conditions may be such that a dangerous amount of poison will drift into a neighboring pasture and injure some of the stock feeding on the grass. Stock should certainly not be allowed to graze on headlands and turnrows in fields which are being poisoned. The same applies to chickens, turkeys, and other fowls. The only fatalities the writers have observed in the course of poisoning work have been in the case of chickens and turkeys running in poisoned fields and picking in the débris covered with a heavy dosage of poison, where the machine had stopped and covered the ground rather thoroughly.

PLANT INJURY BY CALCIUM ARSENATE.

It is well to explain briefly the usual nature of arsenical injury to cotton plants, as there is a tendency on the part of inexperienced

operators to blame the poison for any form of plant disease. Plant injury by soluble arsenic ordinarily is termed "burning," and this word probably describes the appearance of the condition better than any other. The plants look very much as if they had been burned or scalded by some hot application, especially in cases of severe injury. The leaves and terminals droop and the young and more tender shoots wilt badly. This is followed very shortly by the death and drying of the most seriously injured tissue, causing lighter colored spots of dead tissue to appear over the leaves. In cases of mild injury this frequently involves only a sort of "shot-hole" effect over the leaves, but when the injury is severe the entire leaf is killed and falls from the plant in a short time. In still more severe cases the entire plant may die soon after the application.

One fact which should be borne in mind is that plant injury by soluble arsenic is generally very erratic and depends to a great extent upon the weather conditions prevailing at the time of and directly following the application. It will be noted in the specifications that a maximum limit of 0.75 per cent of water-soluble arsenic oxid is recommended. This does not mean that all material containing more than this amount of water-soluble arsenic will be injurious to the plants at every application. In reality, applications of calcium arsenate containing as high as 3 or 4 per cent of water-soluble arsenic frequently will not burn the plants, but it has been found from a large number of tests that any material running over the maximum limit established in these specifications will burn the plants seriously *when certain weather conditions are experienced*. The most dangerous calcium arsenates are those averaging about 2 or 3 per cent in water-soluble arsenic, as it is possible to make two or three applications of these before any plant injury is experienced.

The most dangerous conditions possible for plant burning are found during showery days when there are alternate showers and bright sunshine. On such a day the plants are moist and the atmospheric conditions ideal for making a satisfactory application of poison, but it has been found that if the water-soluble arsenic content of the poison used is the least too high it will produce very severe injury.

Another point which should be noted is that very serious loss from plant burning may result from a degree of injury which appears very slight at first glance. In many cases the injury is such that only a portion of the leaf surface is burned, comparatively little leaf shedding is caused, and the plants appear to recover completely in a day or two. In reality, however, a very slight degree of leaf burning may assume serious proportions because it causes sufficient plant disturbance to produce a heavy shedding of fruit.

In case of leaf injury the cause of which is doubtful, it is advisable to pick several affected leaves, pack them in a moist wrapper, and send them either to the Delta Laboratory or to the plant pathologist of the nearest State experiment station.

HOW TO APPLY POISON.

AMOUNT REQUIRED PER ACRE FOR EACH APPLICATION.

The quantity of calcium arsenate required for each application varies somewhat with the machinery utilized and with other conditions, such as the size of the plants, etc., but generally it has been found that at least 5 pounds per acre are necessary to make a satisfactory application. Where the machines are operated by experienced men, and especially by Government experts who have conducted this work for a number of years, it has been found that thoroughly satisfactory results can be secured by an average application of about 4 pounds per acre. But where the work is conducted upon a practical farm basis, the dosage used has averaged not less than 5 pounds per acre. Anyone attempting the operation for the first time is more likely to average in the neighborhood of 7 pounds per acre for each application. As calcium arsenate at present prices averages \$0.25 per pound, any reduction in the amount required for each application is quite an important item, but to be on the safe side it is advised that until farmers are more thoroughly familiar with the operation the application should be excessive rather than too light. Properly conducted, the operation has a very large margin of profit and it is poor economy to risk this profit by attempting to save a pound or two of poison per acre.

The greatest factor for further saving in the amount of poison required lies in the improvement of dusting machinery. The figures which have been quoted above apply only to the machines which are now in use in this work, and it is hoped that by further improvement of this machinery it will be possible to reduce the amount. In fact, considerable progress has been made in this respect. When the first experiments were started with power dusting machines it was found impossible to control the weevils on an acre of cotton with less than from 12 to 15 pounds of poison dust. If the dust could be broken up into its finest particles and efficiently distributed, there would be enough material in about every 2 pounds of poison to dust an acre satisfactorily, but the present machinery is not equal to the task of delivering the dust in this form. This matter is being studied very carefully with the hope that further improved machinery can be devised.

CONDITIONS UNDER WHICH TO MAKE APPLICATIONS.

The time of day for making these applications is quite an important point. Thoroughly successful results can be secured only when every part of the cotton plant is absolutely covered by the fine particles of poison dust. It has been found that when the humidity is low and there is any breeze whatever, the dust cloud will drift away above the cotton plants and will not filter down and cover all portions of the plant surface. The best time to dust is when the humidity is high, the air calm, and the plants moist with dew, so that the dust will adhere readily. This condition is experienced generally only at night and thus it has been necessary to do nearly all of the dusting work during the night, early in the morning, or late in the evening.

It has been found that while the weevils can be controlled by applications made under unfavorable conditions, the results are generally very erratic and unsatisfactory, and at best can only be expected to hold the weevils in check without accomplishing any considerable diminution in their numbers. This, of course, means that the application must be repeated at very short intervals and makes the entire operation very risky. Therefore the best economy undoubtedly is to reduce the acreage allotment of the different machines to the point where it is not necessary to operate when the plants are dry or while a breeze is blowing. This will increase the outlay for machinery, but it makes the entire operation much safer. Operation under unfavorable conditions should be attempted only in case of absolute emergency and fields which have been treated under such conditions should be watched carefully to determine whether the requisite degree of control has been secured.

ARRANGEMENT OF POISONING SCHEDULE.

Those features of poisoning which include the number of applications, the time of starting, time of ending, and time interval between applications are of course exceedingly variable and depend upon purely localized conditions. But a number of fundamental factors govern these points which should be understood in order properly to plan the operation. In the first place, as has been mentioned, a certain degree of weevil abundance may be permitted without resulting in any reduction in the cotton crop. Furthermore, it is necessary to control the weevils and hold them below the point of injury for only a limited time until the plants have had an opportunity to set their maximum crop. Another important point which must be considered in this connection is the fact that poison reaches and kills only the adult weevils present in the field and has no effect whatever on the imma-

ture stages developing in the bolls and squares. These immature stages continue developing every day for a considerable period after the application is made. A single application may tremendously reduce the adult weevils present in the field at that time, but they will be replaced very quickly by the new generation which is maturing and emerging. Unless the applications are repeated at the proper time intervals, therefore, freshly emerged weevils will soon become sufficiently abundant to counteract all the benefit which may have been secured from the first treatment. In some cases one or two applications may control the weevils sufficiently to permit the formation of a considerable crop of young bolls, but unless these bolls are protected by continued applications the weevils usually will multiply with sufficient rapidity not only to infest the squares present but also to prevent these young bolls from reaching maturity.

SEASON FOR APPLICATIONS.

When it was first found possible to kill at least a certain percentage of the weevils by poisoning, it seemed that the best results would be secured by early season applications, thus deriving the double benefit of killing the weevils then present and preventing the development of their potential progeny. Consequently the first tests were almost entirely early season applications. But it was soon found that far more profitable results were secured by treatments later in the season. Thorough studies on this point have since shown quite definitely that by far the greatest profit is derived by making the applications at the critical time when the weevil injury is just beginning to exceed the normal shed of the cotton plants. Another important point is that the plant is fruiting so rapidly at this time that every day of retardation of weevil infestation means a great deal in additional cotton production.

The time when poisoning should begin has almost no relation to the size of the cotton plant and is purely a question of weevil abundance. Such factors, however, as the size of the farm or field involved will determine very largely the basis upon which poisoning can be planned. For example, in some districts where the cultivated areas are large and more or less consolidated, weevil injury is very evenly distributed, owing to the fact that the weevil adults emerging from hibernation in the spring usually concentrate on the first fields they reach and do not seriously infest the more distant fields until they have practically overtaken the fruiting of this near-by cotton. This condition is found in many portions of the cotton belt and is particularly pronounced in the district where the majority of this Department's tests have been conducted in the past, namely, the Mississippi Delta region of Louisiana, Arkansas, and

Mississippi. Here the plantations are fairly large, usually involving at least 500 acres of cotton in a single organization and frequently a much larger area than this. Under such conditions the poisoning is conducted upon the heavily infested fields with a two-fold object: (1) To secure a reduction in weevil injury upon such fields, and (2) to reduce the numbers of weevils to the point where they will not migrate to the adjoining cotton. It has been found that by operating under such a system it is practically never necessary to poison the entire acreage. Complete economic control of the weevils for the entire acreage can be secured by concentrating on the most heavily infested cuts early in the season and thus preventing weevil multiplication and migration. This is particularly advantageous in that it distributes the cost of poisoning over a much wider area than would otherwise be the case. On the other hand, this system has the disadvantage, which will be discussed later, of requiring a rather complicated organization for conducting the poisoning work.

In districts where the cleared areas are smaller, or farther South where the weevil mortality is so low during the winter that hibernation is possible practically throughout the fields, a more generally distributed infestation is found early in the season and it becomes necessary to treat all fields alike. This is especially true in districts of small farms where the fields are comparatively small in extent and are more or less surrounded by weevil hibernation quarters. Under such conditions the only safe method of procedure is to poison the entire area alike, and this naturally requires a larger amount of poison per acre than is the case where it is necessary to poison only a portion of the crop.

TIME OF STARTING POISONING.

Many studies have been conducted upon the subject of determining the proper time for starting poisoning, but so far no thoroughly satisfactory simple method has been devised. In order to secure uniformity, in studies conducted during the past, a system of what is termed "percentage of infestation" has been utilized. This means the percentage of squares present in the field which are weevil-punctured. While this is fairly simple of determination, a certain amount of care is required if false conclusions are to be avoided. The method utilized throughout this work has been to examine a hundred or more squares at several points in a field—usually the four corners and the center, although this is not generally necessary under ordinary farming conditions. The percentage of these squares which are weevil-punctured is noted and serves as a basis for the poisoning operations. In this connection, however, it should be noted that weevil

injury is frequently distributed over the plants very unevenly, as the weevils display quite a pronounced tendency to concentrate on the upper portions of the plants, and percentage counts should be based on an examination of all squares on the plants rather than on squares examined at random on the upper portions. Naturally the percentage of injury which can be permitted varies with the stage of the cotton plant, but it has been found that usually, if 10 to 20 per cent of the squares are punctured early in the season, practically no harm results. The number of punctured squares gradually increases until later in the season as high as 60 per cent or more can be punctured without any reduction in crop yield. To put off poisoning until there is such a high percentage is not advisable, however, owing to the rapidity with which weevils multiply after they reach this point, and thus exhaust the square supply and start attacking the young bolls. The majority of the poisoning operations in the past have been planned so as to start when about 15 to 20 per cent of the squares were punctured and then to repeat often enough to prevent the infestation from getting above about 25 per cent until the crop is set and the bolls are safe from weevil puncturing. In some cases where it is particularly desirable to confine the weevils to a certain cut and prevent any chance of migration, it is well to start at a somewhat lower percentage and continue even later, but where the only object in view is the benefit to the particular cut poisoned, there is apparently little to be gained from starting applications before at least 15 per cent of the squares are punctured.

TIME INTERVAL BETWEEN APPLICATIONS.

The question of the time interval between applications is very important and one on which only conditional advice can be given, since it varies under different local conditions. In the past, once the applications were started they were generally made once a week as long as this seemed advisable or necessary. In reality, however, this selection of a time interval of one week was purely arbitrary and more recent results seem to indicate that in the majority of cases much better results can be secured by shortening this time interval. The effectiveness of a single application of calcium arsenate is decidedly limited in its duration. Its persistence on the plants naturally depends to a considerable extent on conditions prevailing at the time of application and immediately thereafter. In fact, while a very high percentage of control is secured during the first day of the application, this decreases the second day, and by the fourth day there is generally little or no effect. This short interval of effectiveness is due to two factors: (1) The poison is either washed or blown from the plants, and (2) new foliage is developed so rapidly that

after a few days a great deal of unpoisoned tissue is present, which thus reduces the chances of poisoning the weevil.

A four or five day time interval is best. This not only controls the brood of adults which were present when the applications were started, but also controls their progeny. Under average weather conditions the immature stages developing in the cotton forms at the time when an application is made will continue emerging over a period of at least 12 days. In other words, if the cotton can be kept poisoned thoroughly for a period of about 12 days, the weevils and their progeny are thoroughly controlled. Results vary of course with weather conditions but, generally speaking, two applications with a four-day interval have been found as effective as three or four applications with an interval of a week or more. If conditions are anywhere approaching normal about three applications with a four-day interval will usually reduce the weevil infestation to such an extent that it will be possible to stop poisoning, and in most cases this degree of control has been sufficient to persist during the remainder of the season. Another important point in this connection is that where a 7-day or 8-day interval is used and anything happens to interfere with the schedule, as it often will, the interval may be so extended that practically all control will be lost and the operation will become a complete failure; whereas, when the shorter interval is attempted, any mishaps will still leave the applications sufficiently close together to give a fair degree of control and the worst that can be expected is the necessity of making one or two extra applications.

It should also be taken into consideration that when the short interval is used the infestation can be permitted to become decidedly higher than would otherwise be safe. In other words, the control is so positive and the reduction of weevils so great that it is usually safe to permit the weevil practically to reach the point of becoming injurious to the cotton before making any application.

The machinery requirement must be considered very carefully in connection with the time interval between applications, as the acreage which can be handled by any particular machine is proportionately decreased as the interval is shortened. This of course increases the investment in machinery required per acre. But this cost is offset by the decrease in the number of applications necessary and the consequent reduction in cost of poison and labor. It is offset to an even greater extent by the better control secured and the resultant higher yield of cotton. Of course at present the machinery supply is decidedly short and machines are now high in price compared to what they will be in the future when their production is standardized, so it is quite a problem to determine just how much the acreage allotment for each machine can be reduced without making the ma-

chine investment per acre too high. On the other hand, it is undoubtedly the wisest policy to utilize methods which will give the greatest possible degree of control during the first few years when it is necessary for everyone to feel his way, more or less, in arranging the poisoning schedule. Consequently, it is urged that poisoning be attempted only under such conditions as will justify a sufficient machinery outlay to permit poisoning at about a four-day time interval.

NUMBER OF APPLICATIONS.

The question as to the number of applications is closely correlated with that of the time interval and is one which every man must decide for himself by experience, as the number will vary widely under different conditions. In the large Delta plantations, where the majority of the work has been conducted in the past, it has been found that weevil control throughout the season in the cuts most heavily infested and requiring the earliest treatment in the spring has necessitated from four to six applications with a time interval of one week. Other cuts more distant from hibernation quarters and thus more lightly infested required three, two, one, or no applications. In two years' work on thousands of acres handled on this basis, the average number of applications for all cotton acreage involved has been something less than two. Where infestation is more uniformly distributed at the outset and general poisoning is necessary, it has been found advisable to figure on an average of about four applications, and in case of an excessively rainy season, five or six applications. These figures are based on a one-week time interval, as this interval has been the one adopted in the majority of work so far. With a shorter time interval, however, control can be secured with about three applications. This office is now planning to open a number of small experiment stations in nearly all representative districts of the cotton belt. By conducting control tests at all of these at the same time it will soon be possible to designate much more definite rules of procedure under the varying conditions found in these different districts.

TIME TO STOP POISONING.

The time to stop poisoning has been more or less covered by the discussion of the number of applications but it is probably well to outline briefly the conditions governing this. The idea is to maintain weevil control below the point of loss to the crop long enough for the plants to set as many bolls as they can mature and also to protect these beyond the danger of weevil puncturing. Furthermore, there is nearly always a time when the plants cease to retain any more fruit. In many cases they not only discontinue squaring and blooming but shed the young bolls as fast as they are

formed. This usually means that the plant has reached the limit of its ability to mature fruit. Naturally there is no advantage in attempting to protect these forms, and poisoning during this period, if conducted after the retained bolls are sufficiently large to escape weevil injury, is bound to be profitless. The time when this condition is reached varies widely with the season as well as with the soil fertility, and these factors must always be taken into consideration in deciding whether additional poisoning is justified.

EFFECT OF RAIN ON AN APPLICATION OF POISON.

The effect of rain upon the application of calcium arsenate is a subject of much importance. Experience has shown that a certain amount of rainfall is desirable during the poisoning operations as it induces the formation of dew, makes conditions more nearly ideal for dusting, and apparently increases the amount of mortality secured from the applications. Poisoning operations have been conducted during periods of extreme drought when there was almost no dew formation, but under such conditions it has been very difficult to secure a thorough degree of control. On the other hand, excessive rain is detrimental, owing to the difficulty of getting the poison to stay on the plants long enough to control the weevils. This was especially true during some of the work in the extreme southern districts in 1919. The rains encountered in this work were excessive and in many cases occurred almost daily. Under such conditions weevil poisoning can easily become an absolute impossibility but, as far as that is concerned, such conditions make it practically impossible to raise cotton at all.

It has been found that when an application is made under unfavorable conditions and the plants are dry, even a slight shower occurring a short time later will wash off practically all the dust, while if conditions during the application are more favorable for a large quantity of the poison to adhere to the plants, a much heavier rain will not interfere seriously with the effect of the treatment. As a general rule it seems advisable to repeat an application immediately if a drenching rain falls within 24 hours after treatment. Until more information is secured on the subject, it undoubtedly will be best to follow some such rule as this, but the question of degree of weevil infestation and the conditions under which the application has been made should undoubtedly be considered in connection with the question of whether the application should be repeated.

STARTING POISONING IN THE PRESENCE OF A COMPLETE INFESTATION.

Many farmers make no move toward weevil poisoning until the crop is seriously infested and in fact almost totally destroyed by the

weevils. Then they want to get action immediately and desire to make a hurried purchase of calcium arsenate and dusting machinery to try to save the situation.

To secure control after the weevils have become excessively numerous and have punctured nearly all of the fruit is very difficult and usually involves the use of excessive dosages of poison at short intervals and, furthermore, requires an unusually large number of applications. Consequently the operation is very expensive at best and is also exceedingly hazardous. A very short delay under such conditions is extremely dangerous. The writers do not advise anyone to start poisoning under such conditions with a view of protecting the plants sufficiently to *permit the setting of a new crop*. Sometimes a certain amount of poisoning under such conditions is extremely profitable, as, for instance, when a fair crop of young bolls has been set but is still in danger of weevil attack, owing to the fact that the bolls have not yet developed beyond the point of injury. When the weevils become excessively abundant in such a crop they quite frequently not only overtake the square formation but also destroy a high percentage of the bolls, and poisoning at this time will often save the bolls which are already present on the plants. Since these bolls require protection for only a very short period, it is possible to make perhaps two applications under such conditions and thus retard the weevils sufficiently to eliminate injury to the bolls. It should be remembered, however, that this is quite a different proposition from starting in and attempting to control the weevils to the extent of permitting new squares to develop, bloom, form bolls, and reach maturity.

EARLIER SEASON TREATMENT OF ISOLATED INFESTATIONS.

The expense of weevil poisoning can be considerably reduced in many cases by localized treatment of the most heavily infested patches early in the spring. Often only a few acres in a large field will be infested early in the season. These may be distributed along a strip of timber or may adjoin barns, cabins, or other hibernation quarters. The weevils tend strongly to attack the largest plants available on emergence in the spring, and in case of any inequalities of soil fertility such as are very commonly found, it will generally be noted that the weevils will concentrate on the patches of larger cotton. Under any such condition it is often possible greatly to reduce the infestation of the entire field and to delay considerably the date of general poisoning by going into these isolated spots fairly early in the season and treating them thoroughly before the weevils have an opportunity to spread.

ORGANIZATION OF POISONING OPERATION.

The organization of the poisoning operation will differ considerably with variations in the size and type of the farm involved, but in general may be roughly classified into three groups: First, the large plantation operation where the poisoning is conducted by a separate organization on a wage basis, all crops being treated regardless of tenantry; second, the operation on a large plantation where the treatment of each crop is left to the individual tenant; third, the operation on the small farm where all the poisoning is conducted by the owner and his laborers.

The majority of the work which has been conducted by this department has been located on large plantations which are operated on a tenant basis. Under this form of operation each tenant is in a way an independent farmer in that he has a particular crop for which he is responsible, but at the same time he is operating under the direction of the plantation manager and deriving more or less support from the plantation, paying as a rule a certain proportion of the crop yield in lieu of rental. This condition complicates the poisoning situation. Some planters desire to purchase small-scale machinery for each tenant, leaving the treatment of his crop to the tenant and making this a part of the regular farming operations. Theoretically, the planter would seem by this arrangement to get the work done for nothing. In reality, however, the tenant's time is so fully occupied by his regular duties that he can conduct such work only by neglecting other necessary operations. Furthermore, it has generally proved impossible to get the operation properly conducted if left to the individual tenant. This not only means that the opportunity for weevil control is lost on their crops but that these fields become a menace to the adjacent cotton which may have been properly poisoned. *Weevil poisoning is a plantation and not an individual field proposition.* For this reason nearly all the dusting work which has been done in the past has been organized separately from the regular routine operations of the plantation. Separate labor is secured and assigned to the poisoning operations and applications are made regardless of tenantry or crop arrangement, and are based purely on the distribution of the weevils over the place. This calls for skillful supervision, and where the property is large, involving the use of a considerable organization, it is generally found advisable to employ a competent man to take charge. This arrangement is particularly desirable at the present time, since the operation is so new and there is still so much to be learned about the most economical means of procedure.

The farmer who cultivates his own crop, or at least does so to a considerable extent, is in much closer touch with the progress of

events on his place and has a much smaller area to consider. Under such conditions he can watch his cotton very thoroughly for weevil outbreaks and is usually fully informed on weevil distribution and abundance throughout his fields. Furthermore, under such conditions poisoning is a comparatively minor operation, and by the use of hand guns or small-capacity traction dusting machinery it is possible for him to fit the weevil-poisoning work into his regular operations and handle it with little or no interference. Of course, as a rule, his fields are smaller than on a large plantation and thus it is usually necessary for him to poison his entire crop.

In a number of instances several neighbors have planned to enter into some agreement and purchase a traction-power machine cooperatively with the idea of treating their several crops with the same machine. Theoretically this arrangement seems a very good one, but there is considerable room for doubt concerning its practical working. As has been pointed out, weevil poisoning is generally an emergency proposition and the work must be done at the right time or the entire operation may be imperiled. Consequently, the situation which would develop in case the weather should interfere with a set schedule for machine operation on several places can easily be imagined. Crops belonging to the different men would require treatment at the same time and it would simply be contrary to human nature if friction did not develop under such conditions.

DUSTING MACHINERY TO USE.

The selection of proper dusting machinery is undoubtedly equally as important as securing the correct poison. At the outset of the poisoning work an attempt was made to utilize or adapt existing types of dusting machines such as have been used for truck crops or orchard dusting, but it was soon found that cotton dusting required highly specialized machinery. All dusting operations which had been conducted previously had been in conjunction with more or less intensively handled crops where the labor supply per acre was generally rather plentiful and where the labor was of a fairly intelligent type. In the culture of cotton, however, dusting is placed on an extensive basis where it becomes a large field operation and the machinery must be made as efficient, fool-proof, and simple as possible.

The success of cotton dusting is so dependent on thorough distribution of the poison that any attempt to utilize a means of application which does not give this thorough distribution is certain to result in absolute failure. Many farmers have been accustomed to use the "bag-and-pole" method of poisoning for leafworm control. Such a method of application is suited to leafworm control where large

areas of plant tissue are devoured by the insects and the chances of poisoning considerably increased, but it will not furnish a sufficiently thorough distribution to result in control of the boll weevil.

A special Farmers' Bulletin (1098) has been issued by the Department of Agriculture on the subject of dusting machinery for the cotton boll weevil, and everyone contemplating poisoning is advised to secure a copy of this and study it thoroughly.

So far only three types of satisfactory dusting machines have been developed and placed on the market, namely, the hand gun, the wheel-traction machine, and the engine-power machine.

HAND GUN.

Several satisfactory models of hand guns are now on the market and may be purchased at from \$15 to \$25 each. Each machine consists of a small hand-operated fan and hopper slung from the shoulder of the operator, which is carried through the field, poisoning a single row of cotton at a time. Unfortunately these machines are very difficult to operate. The labor involved is strenuous, to say the least, since the operator must walk through the field at a very fair pace and bear the strain of carrying, directing, and cranking the machine. It has been found that operating for a short period of time, a man can cover about an acre an hour with one of these guns, but he can not continue at this rate for more than an hour or so. Owing to the necessity of poisoning when the plants are moist with dew, hand-gun work can usually be conducted only during the early morning or late evening. Generally speaking, this means from about 4 or 5 o'clock until 8 or 9 in the morning, and from about 6 o'clock to dark in the evening. About the best speed that can be attained is in the neighborhood of 5 acres per day for each man. If two men are available for each gun, it is possible to change occasionally and thus speed up the work so that the area covered by the single gun during the day is somewhat increased, but even under such conditions it is hardly safe to count on an average of more than 5 acres per day for each machine. Figuring on a four-day time interval, this would mean that each machine would cover about 20 acres, but in reality, with loss of time due to various causes which is certain to be experienced, and with delay due to inability to operate under unfavorable conditions, it is certainly not safe to figure on an average allotment of more than 15 acres to each hand gun. It would undoubtedly be much better to figure on about 10 acres for each hand gun, and, if possible, to distribute the operation of this gun between two different laborers.

In many cases farmers planting from 40 to 100 acres of cotton do not feel justified in purchasing large machines and desire to under-

take weevil poisoning by the use of a number of hand guns on this area. This has generally proved very unsatisfactory. The labor requirements of the guns are so great and the operation so laborious and difficult that labor troubles are certain to develop under any normal condition and this has generally resulted in preventing anything like a satisfactory schedule for poisoning work.

One important use of the hand gun is in conjunction with power machinery. A great many fields have certain portions which are very difficult to treat with power machinery, owing to the presence of ditches, stumps, short rows, or similar obstacles. Attempts to treat these portions of the fields with large machinery greatly reduce the rapidity of the operation of the machine and frequently the cotton is injured by being tramped and driven over. Under such conditions the efficiency of the large machine is much increased if a few hand guns with which to treat these difficult portions are available for use at intervals.

Hand guns are also of great value for the early-season work in treating isolated spots of infestation which are often comparatively small in extent. In much of the work which has been conducted in the past, hand guns have been used in such fields for the first application or two and a sufficient degree of control secured from this work to make it possible to defer starting general poisoning with a large machine until some weeks later than would otherwise have been the case.

Several instances have been noted where hand machines have been offered for cotton dusting purposes with the distributing system divided between two nozzles, the idea being that two rows could be treated at each trip. None of the machines manufactured at present have more than enough fan power to treat a single row satisfactorily.

A number of hand guns have been offered for use in cotton dusting with the blower constructed so that the dust delivery is intermittent. As such guns are usually equipped with a bellows serving as a blower the powder is expelled only in recurrent blasts. These are not satisfactory for cotton work since it is necessary that the gun discharge the dust continuously in order that uniform poisoning of all plants be secured while the operator proceeds along the row.

As has been stated, hand-gun work is mainly conducted in the early morning and late evening, and this limits very much the amount of territory which can be covered each day. Operation during the night, however, is often entirely feasible and the results from such operations are usually better than where treatments are attempted during the day. Very satisfactory hand dusting can be done at night by the aid of a small oil or carbide light attached to the hat of each operator, or, in some cases, several hand guns may be

worked together as a group if some kind of torch or contractor's flare is placed at the row ends to provide light.

Another way of reducing the amount of labor involved in hand dusting is by the operation of the machine from muleback. This has been tried on numerous occasions and is generally much more satisfactory than by walking.

POWER DUSTERS.

The earliest work on weevil poisoning was conducted entirely with hand guns, as very small areas were treated during the strictly plat-test stage of the work. Ordinarily the next step in development of dusting machinery would have been to produce something of slightly larger capacity, but owing to the rapid development of the work at this stage, attention was transferred from the development of hand guns to that of blowers of the largest possible capacity, namely, the engine-power machines. In this case the duster was a horse-drawn machine with the fan and feeder operated by a small gasoline engine mounted on the platform. This machine had a distributor extending across the rear end with five nozzles spaced $4\frac{1}{2}$ feet apart, thus covering approximately five rows. Several models of these machines were devised and placed on the market and were used rather extensively during 1918 and 1919. It was found that they would cover from 6 to 10 acres an hour while in operation but that the loss of time due to mechanical difficulties was so great that a machine seldom averaged over 40 or 50 acres for the day's operations. Continued use of these machines soon made it obvious that they were too complicated and cumbersome to be thoroughly satisfactory for cotton-dusting work. Probably the most serious difficulty was the gasoline engine. Another great difficulty was found in constructing a thoroughly satisfactory distributing system for spanning five rows. There was considerable length of pipe extending out beyond the machine on both sides and as this was necessarily made very heavy, the weight caused almost constant breakage due to excessive vibrations and jarring. In many cases the distributors of these power dusters were cut off so as to cover only three rows at a time and they really treated more acreage throughout the season than when they were arranged to span five rows, owing to the greater convenience in handling the machine over the field, around stumps, fences, etc., and the decreased loss of time from breakage.

These power machines were placed on the market at prices ranging from \$400 to \$600 and this price seemed high for the work they could accomplish. Consequently it was desirable to devise a machine which would eliminate the gasoline engine and span only three rows

with its distributor and which could be sold at a more reasonable price. The only answer to this problem which has been developed so far is the wheel-traction or cart type of duster.

WHEEL-TRACTION OR CART DUSTERS.

For the wheel-traction duster a light two-wheel cart is utilized and the power for driving the fan, feeder, etc., is derived from the wheels of the cart. This duster is pulled by two mules and is operated by one man instead of two. By the beginning of 1919 a tentative model had been produced which was placed in the field and operated on a practical basis throughout that season. This machine proved eminently satisfactory in spite of the fact that it was very crudely constructed, and it was selected as the most desirable type for general use in cotton dusting on a large scale. As built, it proved far simpler and easier to operate than the power machines and was especially valuable for its convenience in driving through the field. A number of duster manufacturers became interested in this type of machine and several models based somewhat on this idea are now on the market and others are in the course of construction. These differ widely and embrace the ideas of individual designers, but the general principles of construction are more or less the same. Practically all of the machines are built with an arched axle providing a 42-inch clearance beneath the arch and having a tread of about 48 inches, thus enabling satisfactory operation in any cotton rows not narrower than about 36 inches.

It has been found that under normal conditions one of these wheel-traction machines will probably average about 25 acres per night of operation. It may exceed this amount under very favorable conditions but it is not safe to figure on a greater average than this. As has been pointed out, it is undoubtedly desirable to provide equipment for treatment at a time interval of about 4 days. Owing to rains and other interruptions, it is undoubtedly not safe to figure on more than three days' operation out of the four. Consequently, about the best that can be expected of one of these machines is that it will handle in the neighborhood of 75 acres of infested cotton throughout the season.

So far the machines of this type which have been built have been placed on the market at a rather high price, ranging from about \$350 to \$500. The manufacturers have taken extreme precautions to place the highest quality of workmanship and material in the construction and this has resulted in making the price of the machine higher than is generally desirable. It still remains to be seen whether or not this cost is justified by increased efficiency of the machines. It seems quite probable that other machines built on

much the same design will be placed on the market at a fairly early date at a lower figure. From present prospects the minimum sales price for such a machine will be in the neighborhood of \$200.

The high cost of this machinery is particularly unfortunate, as it will tempt the farmer to expand his acreage allotment for each machine as much as possible by increasing the time interval between applications. This is bound to be a hazardous practice. In fact, if a grower is confronted with the problem, it would be far better for him to select a limited acreage of his best yielding land where the weevil damage is highest and treat this thoroughly and properly, ignoring the rest of his crop, than risk the success of the entire operation by attempting to make a machine cover too much acreage.

NEED OF AN INTERMEDIATE TYPE OF DUSTING MACHINE.

As the situation now stands, there is no dusting machine on the market intermediate between the hand duster and the wheel-traction or cart type of duster. Inasmuch as hand dusters are generally unsatisfactory on fields larger than about 25 acres, and as the cost of a cart duster is such that a man is seldom justified in buying one for use on less than 75 acres, no equipment suitable for a man cultivating between 25 and 75 acres of cotton is available and his problem is a difficult one. When a sufficient supply of labor is available, however, it may be possible for him to utilize hand guns; and where the soil fertility is particularly high, the purchase of a cart machine for use on the small acreage may be justified. Several types of devices, such as saddle guns or single-wheel machines for operation between the cotton rows, are being studied, but the process of perfecting and producing them will require considerable time.

LIGHTING EQUIPMENT FOR DUSTING MACHINES.

The question of lighting any cotton-dusting machine requires particular attention. As has been explained, an application of poison gives the best results when it is made at night; therefore a thorough lighting equipment must be provided. This has been a serious difficulty in the past and all kinds of lights have been tested. So far only one type has been developed which gives any assurance of being thoroughly satisfactory. This is a special model of acetylene light which utilizes a compressed carbide cake for fuel. These lights have been constructed for cotton-dusting machine work and apparently the majority of the machines to be placed on the market will be equipped with them. At any rate, anyone purchasing a dusting machine should be sure that it is provided with a simple and satisfactory equipment that will give ample light for avoiding stumps,

ditches, etc., while driving. It must also afford sufficient rear illumination over the nozzles to enable the operator to make sure that the dust flow is regular.

CAPACITY OF MACHINES FOR TREATING SEVERAL ROWS PER TRIP.

In the earlier stages of the work it was attempted to make machines with adjustable nozzles that could be aimed directly at the rows being treated. It was soon found, however, that cotton rows vary so greatly in spacing that such an arrangement was impractical. Moreover, it was unnecessary. The entire poisoning operation is based on the plan of creating a thick cloud of dust which will envelop all parts of the cotton plants and coat them thoroughly. Consequently, all width-adjusting devices were eliminated and the nozzles have since been spaced about $4\frac{1}{2}$ feet apart. These nozzles are provided with deflecting plates or some similar spreading device which causes the dust clouds from the different nozzles to unite very quickly after leaving the machines, so that a uniform "fog" extending from row to row is created. Under such conditions it does not matter whether the nozzles are directly over the rows or between them. It has also been found possible under certain conditions to cover more rows than the nozzles actually span. This suggestion, however, should be taken very conservatively, as considerable experience is required in the use of dusting machinery to determine just how far the drift can be considered as thoroughly effective in dusting. Until the operators have become thoroughly experienced in this work it is probably the best plan to figure on taking only as many rows as the distributor will actually span.

FEATURES TO BE NOTED IN PURCHASING COTTON-DUSTING MACHINERY.

For the benefit of those planning to purchase cotton-dusting machinery, the following brief outlines have been prepared giving the most important features which should be considered in order to make sure that the machines will be satisfactory.

HAND GUN.

The total weight should be not over 20 pounds when filled with poison dust.

The hopper should hold about 4 to 7 pounds of calcium arsenate and it should be possible to put out practically all of this before refilling.

The balance of the gun should be such as to cause the least strain on the operator, that is, the heavy parts of the machine should be as close to his body as possible.

The gun should hang naturally so that the nozzle is directed at the tops of the cotton plants without causing any undue strain on the operator in aiming it.

The capacity of the feeding mechanism should be sufficient to permit the use of a delivery of at least 1 pound in 5 minutes at the ordinary rate of cranking.

The feed should be quickly and positively controlled. Adequate facilities should be provided for lubrication of working parts.

The fan should create sufficient air current to break up the dust into a cloud and force it to spread over all parts of the plant.

The gun should be well constructed throughout so that breakage is reduced to a minimum.

All parts of the gun should be as conveniently accessible as possible for repair or replacement.

WHEEL-TRACTION OR CART DUSTER.

The wheel-traction machine should be light enough in weight and draught to enable an average team to operate it through a full night without undue fatigue.

There should be sufficient axle clearance to avoid plant injury.

The tread should be such that it will straddle a row of cotton without running on the adjacent ones and still prevent the machine from being dangerously top-heavy.

The machine should be properly balanced on the axle to prevent uptilting of the tongue or undue strain on the necks of the team.

All details of construction should be simple, fool-proof, and durable.

The feed mechanism should be subject to quick and positive regulation, varying from a complete cut-off to a maximum delivery of 6 pounds in 5 minutes through the three nozzles at the ordinary rate of walking for the team.

The fan should create sufficient air blast to prevent clogging of the pipes, and to blow the dust throughout the plants under any ordinary weather condition.

The machine should be provided with suitable lighting equipment.

The hopper capacity should be sufficient to hold from 30 to 50 pounds of calcium arsenate.

The distributing system should be provided with a positive lift to regulate the height of the nozzles from vertical to horizontal and should also be arranged to fold in conveniently to permit passage through gates.

The platform should be large enough to accommodate all machinery and the driver and also to carry a barrel of poison.

The driving mechanism should be so arranged that the fan will continue in operation while the machine is turning on one wheel in either direction at row ends.

The running and driving mechanism should be shielded to prevent plant injury or clogging with vegetation.

The method of hitching should allow flexibility which will prevent the load from being thrown on one animal.

All parts should be readily accessible for repair or replacement.

POWER DUSTER.

The engine of a power duster should be as simple and efficient a type as possible and should provide a slight surplus of power over that actually required to operate the machinery.

The truck should be provided with a fifth wheel arrangement and the front wheels should cut under the body to permit short turns.

The distributor construction should be strong enough to carry the wide spread of nozzles.

COST OF POISONING.

Anyone who has read the preceding pages carefully can easily appreciate the futility of attempting to give generalized figures on the cost of poisoning which would be of any value to the individual. The cost to each man is going to be an individual problem and will differ radically in the different fields and in different seasons. Although careful cost figures have been kept in connection with the experiments which have been conducted in the past on both large and small scale work, it is useless to give more than a few generalized statements concerning these. Where the operation has been conducted on an individual field basis requiring in the neighborhood of four applications, it has been found that the cost of poison, labor of application, and reasonable depreciation on the investment for machinery has been in the neighborhood of \$7 to \$10 per acre for the season. On a large plantation basis the investment in poison and machinery has naturally been lower but the additional cost of supervision, etc., has generally been sufficient to offset this difference. At present prices, it is hardly safe to figure on a cost of less than \$2 an acre per application.

GAINS TO BE EXPECTED FROM POISONING.

The gain in amount of seed cotton to be expected from the use of poison is another point which is not subject to definite figures. During the past five years several hundred plat tests have been conducted in such a manner that an accurate comparison in yields was

afforded between the poisoned and unpoisoned plats. Throughout this work the gains have varied from nothing to over 1,000 pounds of seed cotton per acre.

The most that can be expected of poisoning is the elimination of weevil injury. Soil fertility is very important and really becomes the determining factor in the amount of gain which can be secured from the poisoning. One interesting feature of the work which has been conducted so far is the large number of tests on fields which had a fairly low degree of weevil infestation and which have shown absolutely no gain from the operation. In many cases comparable plats have been selected and started with an infestation of 10 or 15 per cent, one plat being poisoned and the other left unpoisoned as a check. In such cases, the infestation of the check plat, instead of increasing as would normally be the case, has been held in check by some climatic condition so that there was only a gradual increase to a maximum of from 35 to 50 per cent of the squares punctured at the end of the season. Usually, under such conditions, no gain in yield is shown in spite of the fact that infestation of the poisoned plat was practically wiped out. In other words, the degree of infestation in the check plat was not sufficient to overtake the normal shed of squares and thus there was no reduction in crop yield. This, of course, illustrates the needlessness of poisoning unless the weevils are sufficiently abundant to injure the crop.

There are many fields where weevil infestation becomes so complete by the middle or latter part of the summer that it would seem advisable to start poisoning, but the plants in these fields may have reached the limit of their production on that soil, thus being unable to take advantage of any protection from weevil attack. This is particularly true of many of the sandy soils upon which the plant produces a very quick crop of cotton and then matures and stops fruiting at an early date. This point is further complicated by variations in the habits of the different cottons. For example, certain varieties of cotton have what is ordinarily termed a "determinate" growth. They make their crop early and then stop fruiting altogether. Consequently, any poisoning under such conditions, regardless of the degree of weevil control secured, is a useless expense unless undertaken for the protection of the young bolls already set on the plants.

In still other cases there are soils of such low potential productivity that even if the entire crop were saved from destruction by the weevil its value would still not justify the expense of poisoning.

To summarize the results of the experiments which can be considered of real value in this connection, it may be said that the actual gains in seed cotton per acre have ranged from about 200 to 1,000

pounds. In these cases the infestation was heavy enough to justify the treatment, and, furthermore, the soil was generally of a decidedly fertile nature. In reality these figures are quite conservative, as they are based on very small plat tests where there was undoubtedly considerable reduction in gain due to the effect of weevil migration from nonpoisoned cotton. This is shown by the general results of a considerable number of the large-scale tests conducted under conditions more or less the same. Unfortunately in large-scale tests accurate figures can not be secured on the increase of yields, but it is obvious from the approximate comparisons made that the gains were very large, being, in fact, considerably larger than those obtained in plat tests under the same conditions. Consequently it seems safe to assume that with fertile soil and a fairly severe weevil infestation average gains of 500 pounds or more of seed cotton per acre are not at all remarkable.

ADVISABILITY OF POISONING UNDER PRESENT CONDITIONS.

The first thing which must be decided by any one contemplating poisoning is whether or not his conditions are such as will enable the operation to be profitable. In case of doubt it would be best for him to forego poisoning. As has been shown, weevil infestation must necessarily be at least fairly severe. Furthermore, the soil fertility must be such that the plants can take advantage of the protection afforded them by poisoning and produce a considerable gain in yield. It is difficult to establish any fixed limits with regard to soil productivity, but for the present at least it hardly seems advisable to attempt poisoning unless the land would make at least half a bale of cotton per acre in case there were no weevils. In fact, if the higher-priced machinery, such as has been mentioned, is utilized, it will probably be advisable to raise this limit somewhat and poison only land capable of making two-thirds or three-fourths of a bale of cotton. This naturally means that a very large proportion of the hill-land cotton will not justify poisoning at present, as the soil fertility is too low. Nearly all hill farmers, however, have at least a few acres of fertile bottom land in their farms which can be utilized for small-scale poisoning work during the first year or two to afford experience in poisoning which will make it safer for them to expand the work later over the remainder of their crop. In fact, regardless of conditions, unless a man is thoroughly sure of being able to conduct the operation just as outlined, it is undoubtedly best for him to undertake it first on only a portion of his cotton, selecting for this purpose the most fertile soil which is subject to the heaviest weevil injury.

A very accurate check plot should be provided; otherwise the question of gain or loss is likely to be more or less problematical. For this purpose several fairly uniform cuts should be selected, subject to about the average degree of weevil infestation in that locality, and only one-half of each cut treated, letting the remainder go untreated as a check on results secured. A little experience of this sort will soon make clear the conditions under which the grower can or can not poison profitably. Of course, this unpoisoned check plot will serve to increase the infestation of the adjacent poisoned cotton, but this slight loss will be far more than offset by the value of the information secured.

Weevil poisoning has in some cases been criticized as possibly tempting the farmer to neglect securing the proper varieties of cotton and cultivating properly, and other important factors or operations which have been learned as a result of hard experience with the boll weevil. On the contrary, by eliminating weevil injury it should encourage the planter to strive for the increased yield which can be induced by good farming, and to emulate the man who practices such a good method of farming that his gain from weevil poisoning is tremendously increased. *No one should slight any other operation involved in the production of the cotton crop just because the plants are being poisoned.* Weevil poisoning can not make cotton. It is up to the farmer and the land to do this, and the best that can be expected of poisoning is to save this cotton from weevil destruction.

CONTROL OF THE COTTON LEAFWORM AND FALL ARMY WORM WITH CALCIUM ARSENATE.

One question which frequently arises in connection with the use of calcium arsenate is whether or not this material will control the cotton leafworm, fall army worm, or any other pests of this nature. It will undoubtedly be as satisfactory for this purpose as any chemical which could be utilized. It is very nearly as poisonous as Paris green to the worms and has the decided advantage of being cheaper and less injurious to the plants. In case anyone desires to utilize weevil-poisoning equipment solely for leafworm control, however, he should bear in mind that he could considerably reduce the expense of the operation without interfering with its effectiveness by mixing equal parts of lime and calcium arsenate and applying this mixture at the rate of about 4 or 5 pounds per acre.

PUBLICATIONS OF UNITED STATES DEPARTMENT OF AGRICULTURE RELATING TO INSECTS AFFECTING COTTON PLANT.

AVAILABLE FOR FREE DISTRIBUTION.

- Cotton Improvement under Weevil Conditions. (Farmers' Bulletin 501.)
 Fall Army Worm, or "Grass Worm," and Its Control. (Farmers' Bulletin 752.)
 Carbon Disulphid as an Insecticide. (Farmers' Bulletin 799.)
 Red Spider on Cotton and How to Control It. (Farmers' Bulletin 831.)
 Bollworm or Corn Earworm. (Farmers' Bulletin 872.)
 How Insects Affect the Cotton Plant, and Means of Combating Them. (Farmers' Bulletin 890.)
 Relation of the Arizona Wild Cotton Weevil to Cotton Planting in the Arid West. (Department Bulletin 233.)
 Studies of the Mexican Cotton Boll Weevil in the Mississippi Valley. (Department Bulletin 358.)
 Argentine Ant: Distribution and Control in the United States. (Department Bulletin 377.)
 Cotton Boll Weevil Control in the Mississippi Delta, with Special Reference to Square Picking and Weevil Picking. (Department Bulletin 382.)
 Collection of Weevils and Infested Squares as a Means of Control of the Cotton Boll Weevil in the Mississippi Delta. (Department Bulletin 564.)
 Pink Bollworm with Special Reference to Steps Taken by the Department of Agriculture to Prevent Its Establishment in the United States. (Department Bulletin 723.)
 Recent Experiments in Poisoning Cotton Boll Weevils. (Department Bulletin 731.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, WASHINGTON, D. C.

- Use of Paris Green in Controlling the Cotton Boll Weevil. 1904. (Farmers' Bulletin 211.) Price 5 cents.
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 Miscellaneous Cotton Insects in Texas. 1905. (Farmers' Bulletin 223.) Price 5 cents.
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 Most Important Step in Control of Boll Weevil. 1908. (Entomology Circular 95.) English and French editions, each 5 cents.
 What Can be Done in Destroying Cotton Boll Weevil During Winter. 1909. (Entomology Circular 107.) Price 5 cents.
 Status of Cotton Boll Weevil in 1909. 1910. (Entomology Circular 122.) Price 5 cents.

- Annotated Bibliography of Mexican Cotton Boll Weevil. 191¹. (Entomology Circular 140.) Price 5 cents.
- Movement of Mexican Cotton Boll Weevil in 1911. 1912. (Entomology Circular 146.) Price 5 cents.
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- Cotton Stainer. 1912. (Entomology Circular 149.) Price 5 cents.
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- Movement of Cotton Boll Weevil in 1912. 1913. (Entomology Circular 167.) Price 5 cents.
- Report on Habits of Kelep, or Guatemalan Cotton Boll Weevil Ant. 1904. (Entomology Bulletin 49.) Price 5 cents.
- Mexican Cotton Boll Weevil, Revision and Amplification of Bulletin 45, to Include Important Observations made in 1904. 1905. (Entomology Bulletin 51.) Price 15 cents.
- Report on Miscellaneous Cotton Insects in Texas. 1906. (Entomology Bulletin 57.) Price 5 cents.
- Proliferation as Factor in Natural Control of Mexican Cotton Boll Weevil. 1906. (Entomology Bulletin 59.) Price 15 cents.
- Papers on Cotton Boll Weevil and Related and Associated Insects. 1909. (Entomology Bulletin 63, 7 pts.) Price 15 cents.
- Hibernation and Development of Cotton Boll Weevil. 1907. (Entomology Bulletin 63, pt. I.) Price 5 cents.
- Notes on Biology of Certain Weevils Related to Cotton Boll Weevil. 1907. (Entomology Bulletin 63, pt. II.) Price 5 cents.
- Ant Enemy of Cotton Boll Weevil. 1907. (Entomology Bulletin 63, pt. III.) Price 5 cents.
- Predatory Bug Reported as Enemy of Cotton Boll Weevil. 1907. (Entomology Bulletin 63, pt. IV.) Price 5 cents.
- Cotton Stalk-borer. 1907. (Entomology Bulletin 63, pt. VII.) Price 5 cents.
- Mexican Conchuela in Western Texas in 1905. 1907. (Entomology Bulletin 64, pt. I.) Price 5 cents.
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- Studies of Parasites of Cotton Boll Weevil. 1908. (Entomology Bulletin 73.) Price 10 cents.
- Some Factors in Natural Control of Mexican Cotton Boll Weevil. 1907. (Entomology Bulletin 74.) Price 15 cents.
- Hibernation of Mexican Cotton Boll Weevil. 1909. (Entomology Bulletin 77.) Price 25 cents.
- Plant-bugs Injurious to Cotton Bolls. 1910. (Entomology Bulletin 86.) Price 20 cents.
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- Argentine Ant. 1913. (Entomology Bulletin 122.) Price 25 cents.

UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 885

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.

December 11, 1920

THE BLACK FLY OF CITRUS AND
OTHER SUBTROPICAL PLANTS

By

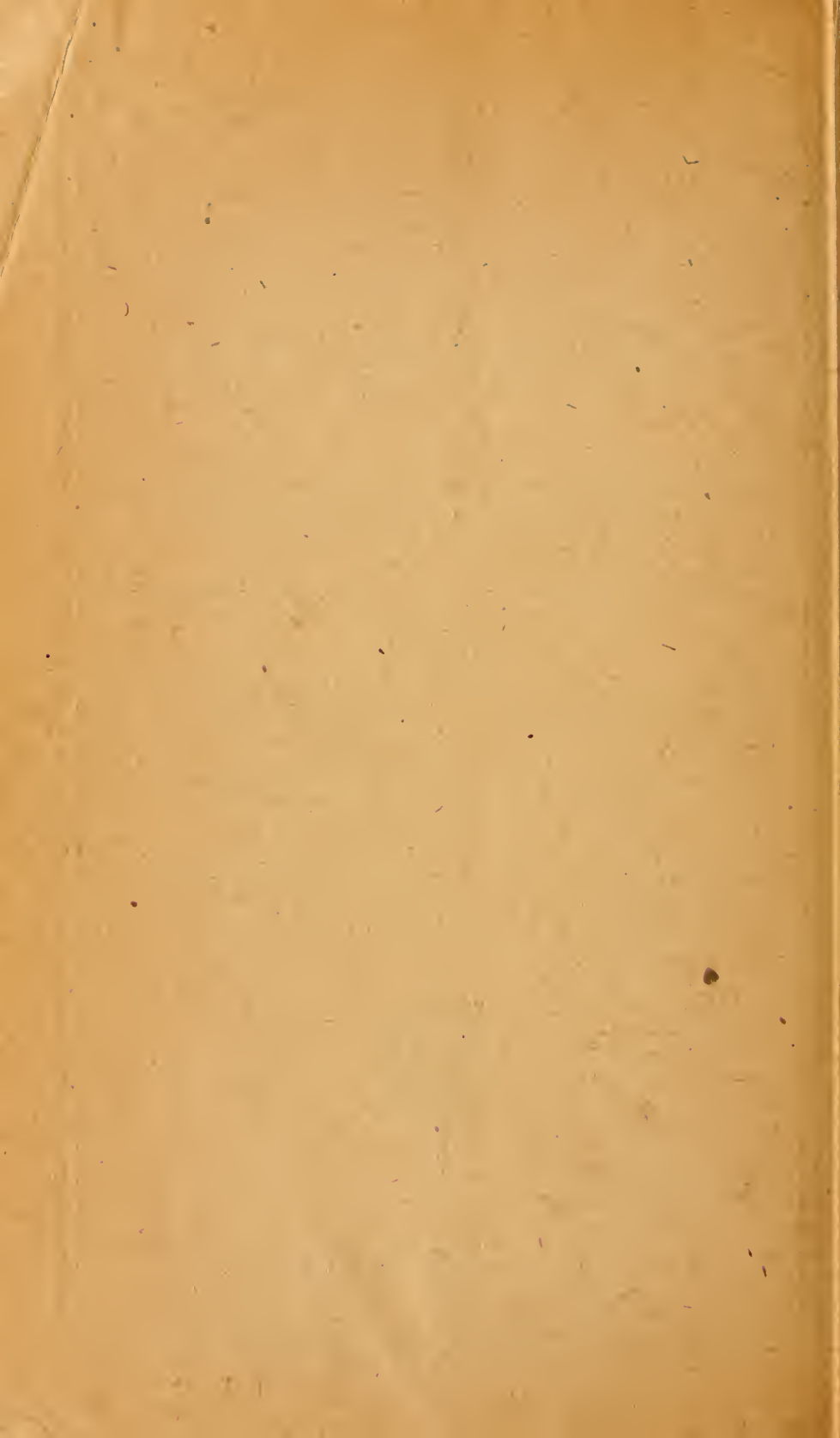
HARRY F. DIETZ, Entomological Inspector, Bureau of Entomology,
United States Department of Agriculture, and JAMES
ZETEK, Entomologist, the Panama Canal

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THE BLACK FLY OF CITRUS AND OTHER SUB-TROPICAL PLANTS.¹

By HARRY F. DIETZ, *Entomological Inspector, Bureau of Entomology, United States Department of Agriculture*, and JAMES ZETEK, *Entomologist, The Panama Canal*.²

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INTRODUCTORY.

The black fly, *Aleurocanthus woglumi* Ashby, known also as the spiny citrus white fly and as the *mosca prieta*, is a tropical pest of the

¹ This work was done in cooperation with the Panama Canal, the second-named author being delegated to work with the bureau's representative. To the various departments and divisions of the Panama Canal which have aided and cooperated with them the authors are grateful. Special thanks are due the health department for providing laboratory space and facilities for carrying on the work, and the authors are indebted to the chief health officers, Col. H. C. Fisher and Lieut. Col. A. T. McCormack, and to the directors of the Board of Health laboratories, Drs. Oscar Teague, Wm. L. McFarland, and Lewis B. Bates, for their encouragement and advice from time to time.

The studies on the life history, habits, hosts, distribution, and control of the black fly in the Canal Zone and the adjoining parts of the Republic of Panama were begun in June, 1918, and the authors have been assisted in this work by Mr. Ignacio Molino, who, as entomological laboratory assistant, deserves special mention for the way he has carried on the work that has been assigned to him. Observations and experiments made by him are given full credit in the following pages.

Practically all the published literature relating to *Aleurocanthus woglumi* has been consulted and the data set forth compared with those obtained in the Canal Zone. Unpublished reports on this insect in the files of the Bureau of Entomology have been consulted, and much that was both interesting and helpful has been obtained in the discussions that one or both of the authors have had with Mr. J. R. Johnston, of the Comision de Sanidad Vegetal de Cuba, and Mr. Harold Morrison and Dr. A. C. Baker, of the Bureau of Entomology. Full use has been made of an unpublished report of Mr. Morrison on the status of the black fly in the West Indies.

² The arrangement of the authors' names is alphabetical and denotes neither seniority nor precedence.

Old World that has made its appearance in the Tropics of the Americas. Its apparently rapid spread in the New World along with the fact that it now threatens to gain entrance into Florida from Cuba and Nassau makes it a pest of special interest from the plant quarantine point of view.

In August, 1917, Mr. Harold Morrison, the explorer in charge of the Mediterranean fruit fly investigations of the Bureau of Entomology, found the insect well established in Cristobal, Balboa, and Ancon in the Canal Zone, and in Colon and Panama in the Republic of Panama. Since the Canal Zone may be regarded as the crossroads of the New World's water traffic, a temporary field station was established at the Board of Health laboratory at Ancon to study the black fly and other tropical insect pests that might be carried by commerce to other parts of the Tropics or to the subtropical parts of the United States.

Aleurocanthus woglumi has several common names. It has been called the black fly, the citrus black fly, and the black scale in Jamaica and is known as the blue fly and the citrus blue fly in the Bahamas. In Florida it is known as the black fly. In literature it has also been referred to as the spiny citrus white fly in order to distinguish it from the common citrus white fly (*Dialeurodes citri* Ashmead). While this insect belongs to the family Aleurodidae, known as white flies, the term of white fly does not fit it, inasmuch as it is black or dusky in all stages. In Spanish countries the insect is known as *mosca prieta*, which means black fly. There is a minor objection to the use of the name black fly, inasmuch as it is the common designation of biting buffalo gnats, family Simuliidae. Nevertheless, on account of the common and wide use of the name "black fly" for this aleurodid in English-speaking countries and of its Spanish equivalent in Spanish-speaking countries, it would probably be impossible now to secure the general adoption of any other name. There is little likelihood of any confusion arising in discussion or literature in the use of the term black fly for this insect as an enemy of citrus and other subtropical plants.

THE SCIENTIFIC NAME OF THE INSECT AND TO WHOM IT SHOULD BE ACCREDITED.

The black fly was first described by Ashby (3)^s in his article on the black scale or black fly. Although this description is entirely untechnical and is used merely in setting forth the stages in the life cycle, and although Ashby used Quaintance and Baker's manuscript name for the insect, and specifically states that this name should be credited to Quaintance, nevertheless, under the rules of the Inter-

^s Figures in parentheses refer to "Literature cited," p. 53-55.

national Code of Nomenclature, Ashby's name must stand as the author of the species. Quaintance and Baker (31) have written the first and only technical description of *Aleurocanthus woglumi*, although the material that they had at hand did not permit their describing the first to third larval instars of this insect. The complete descriptions of all stages of the insect prepared by one of these authorities are included in this report.

LITERATURE.

There are 33 references to *Aleurocanthus woglumi* in literature. Among the most important of these is the work of Johnston (16, 17), Cardin (7-11), and Hutson (12-15) in Cuba; Ashby (2, 3) and Ritchie (33, 34) in Jamaica; and that of Quaintance and Baker (31, 32) in the United States. Others who have contributed to the literature are Arango (1) in Cuba; Ballou (4) in Barbados; Bragdon (5), Montgomery (19), Newell (22-29), Pierce (30), and Watson (35) in the United States; McCormack (18, p. 30) in Panama; and Zetek (37) in Costa Rica. An unpublished work by Morrison in the files of the Bureau of Entomology covers his observations in Jamaica and Cuba and records his finding the insect for the first time in the Canal Zone. This report has been freely consulted and used by the authors.

No comprehensive publication on the black fly, however, has appeared to date.

A bibliography of the literature cited is given on pages 53 to 55.

ORIGIN AND DISTRIBUTION.

Aleurocanthus woglumi unquestionably originated in the East Indies and from there it has been introduced into the Tropics of the New World, over which it is now spreading. It was first found in India by Maxwell-Lefroy in June, 1910. In the same year it was found in Manila, P. I., by George Compere. In October, 1910, R. S. Woglum, of the Bureau of Entomology, in search of parasites of the citrus white fly (*Dialeurodes citri* Ashmead), found *Aleurocanthus woglumi* at the Royal Botanical Gardens, Ceylon, and it is in his honor that the species is named. From November, 1910, to June, 1911, Woglum found this insect at the following places in India: Gujranwala; Kalimpong, Sikkim; Lahore and Nagpur, Central Province. In November, 1913, Mr. A. Rutherford added Peradeniya, Ceylon, to the Old World distribution of the black fly.

Aleurocanthus woglumi was first sent in to the Bureau of Entomology for determination from the New World in November, 1913, and February, 1914, by Col. C. Kitchner, from Half-Way, Jamaica. In May, 1914, S. F. Ashby, microbiologist of the Department of Agriculture of Jamaica, sent in specimens of this pest from Kingston, and

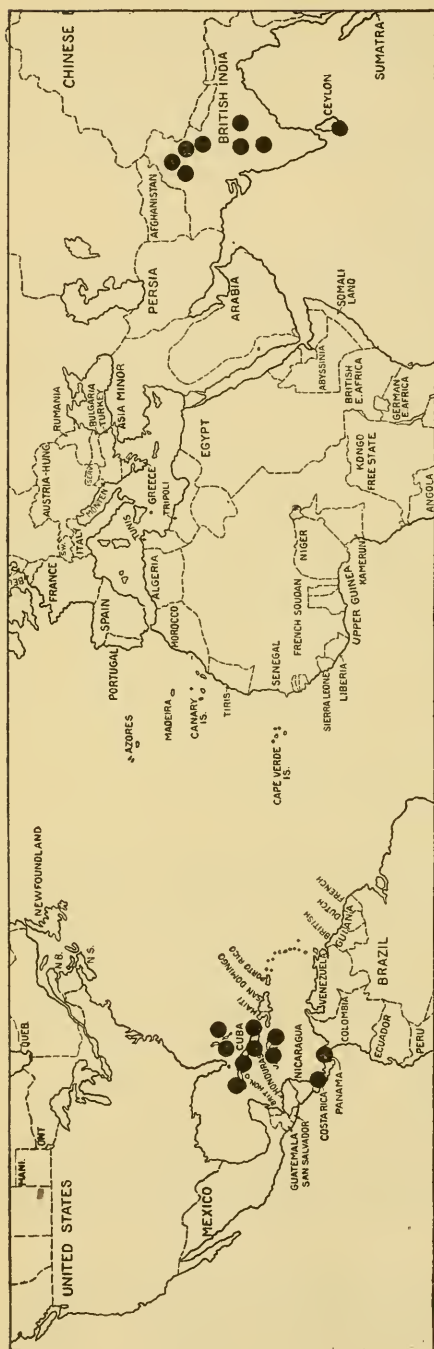


FIG. 1.—World distribution of the black fly (*Ateurocanthus voglumi*).

in 1915 he wrote two papers (2) and (3), indicating therein that it was rather widespread over the island of Jamaica. In February, 1916, Patricio Cardin, entomologist of the experiment station of Cuba, sent in specimens from Guantanamo, Cuba, and in the same month L. J. K. Brace sent in specimens from Nassau, New Providence, Bahama Islands. In 1917 Johnston (16, 17) showed that the insect occurred in Cuba, at Guantanamo and Habana. This same year Ritchie (34) states that "the entire island [Jamaica] is becoming generally involved." In an unpublished report of November, 1917, in the bureau files, Harold Morrison gives an account of the black fly in Jamaica and Cuba, and for the first time called attention to the fact that this insect was established in the Canal Zone and the adjoining parts of the Republic of Panama, having been found by him on citrus and mango trees in Cristobal, Ancon, and Balboa in the former place and in Colon and Panama in the latter, in August of that year. In the early part of 1918 Dr. W. M. Mann, of the Bureau of Entomology, found the pest in the vicinity of Santiago de Cuba, thereby establishing a new Cuban distribution record. In his explorations of the British West

Indies in 1918, Morrison did not find this pest in Barbados, Grenada, Tobago, Trinidad, or British Guiana. The British entomologists of these regions are fully acquainted with this insect and are carefully



FIG. 2.—Distribution of the black fly in the West Indies.

watching for it. Therefore it is safe to assume that the black fly does not occur there at the present time. In his trip to the Virgin Islands in 1917, Morrison did not find it at any places visited by him

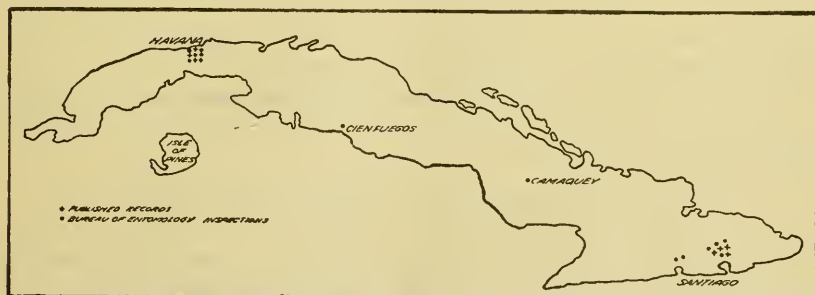


FIG. 3.—Distribution of the black fly in Cuba.

on the islands of St. Croix, St. John, or St. Thomas. Neither did he find it in Porto Rico in his inspections that year.

In 1919, Zetek (37) records for the first time the occurrence of the black fly in Costa Rica, having found it in the vicinity of Limon and as far inland as Peralta, on the Northern Railroad.

The maps show the distribution of the black fly in the world (fig. 1), in the West Indies (fig. 2), and in Cuba (fig. 3).

In the Canal Zone this insect has been found at Cristobal, Mount Hope, Gatun, Frijoles, Pedro Miguel, Miraflores, Corozal, Balboa, Palo Seco, and Ancon, and in the Republic of Panama it has been found in Colon, Panama (including the suburbs), the Las Sabanas region north of Panama as far as Rio Bajo, Panama Vieja (Old Panama), and Taboga Island. It was not found at the large citrus plantation at Juan Mina, or at Limon, Summit, Las Cascadas, Empire, Gamboa, Venado, Bracho, Mindi, Toro Point, France Field, or Coco Solo in the Canal Zone, or at Pueblo Nuevo, Matias Hernandez, Arraijan, Chorrera, Chepo, Pecora, or Almirante (Bocas del Toro region) in the Republic of Panama, at all of which points inspections have been made by the authors or by Ignacio Molino.

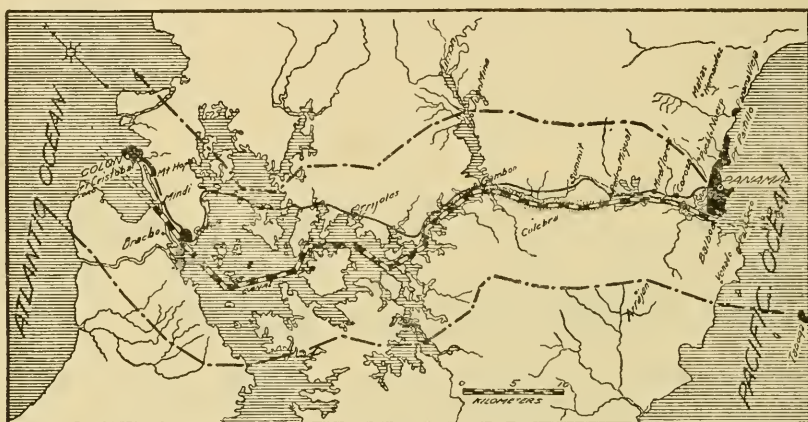


FIG. 4.—Distribution of the black fly in the Canal Zone and adjoining parts of the Republic of Panama.

The map (fig. 4) shows the distribution of this pest in the Canal Zone and adjoining parts of the Republic of Panama.

The hosts on which *Aleurocanthus woglumi* has been found in various parts of the Old and New Worlds will be found under the heading, "Food plants," page 14.

SPREAD OF THE INSECT IN THE NEW WORLD.

Ashby (3) says that *Aleurocanthus woglumi* "was probably brought here [Jamaica] on mango cuttings from India within the last 20 years." Morrison, after his investigation of conditions in Jamaica, believes that "the pest has been introduced certainly within 10 years or even as late as 1910." There is no question that the insect was first introduced into Jamaica from India either on mango or some other host, and that from this focus in the New World it has spread to Nassau, New Providence, Bahama, the Guantanamo and Santiago de Cuba regions of Cuba, and the Canal Zone. The actual time of its introduction into any of these localities has not been determined.

If it is assumed that it was introduced into Jamaica within the last 10 or 12 years, then its spread from there to the places mentioned before has indeed been remarkably rapid, and it is merely a matter of a short time until it will occur throughout Cuba, the Bahamas, and the citrus-growing regions of Central and South America.

There is perhaps only one way that an insect like *Aleurocanthus woglumi* can be introduced from an infested region to an uninfested, suitable, far distant one and become established. This is on a well-infested host plant or parts thereof on which the leaves are allowed to remain, so packed that the various stages of the insect can continue their development throughout the journey, or at least withstand it. This is because there are several checks to its successful establishment: First, a high mortality of the individuals, especially in the early instars or at molting time, if subjected to adverse conditions, such as drying out or heavy rains; secondly, the fact that parthenogenesis occurs in *A. woglumi* just as in other white flies whose life history has been worked out; and thirdly, the fact that the larvæ are not vigorous crawlers and seldom get more than an inch away from the eggs from which they hatch. These factors are considered at length in a discussion of the life history of this insect.

When *Aleurocanthus woglumi* is favorably introduced into a new locality, however, there are several ways in which it may spread and become thoroughly established in a region. These methods are the natural and the artificial. The natural method includes: First, the natural flight or migration of the adults from infested to clean plants; secondly, the carriage of the adults and possibly larvæ by winds. The artificial method includes: First, the carrying of infested plants from one place to another either in the form of pot or specimen plants or in numbers as in the case of nursery stock or as cuttings; secondly, the carrying of adults on vehicles, trains, automobiles, or the clothes of persons passing or working among infested trees.

There is no doubt that the black fly has had at least a half dozen or more chances of becoming introduced into the Canal Zone through the shipment of infested food plants from Jamaica. In the Canal Record for July 31, 1912 (6), this statement appears: "Plants and shrubs have been received at Ancon from Director Wilder of the Botanical Gardens at Honolulu, from the director of Hope Gardens, Kingston, Jamaica, and from the Department of Agriculture in Washington, D. C." The Record gives a large list of plants, several of which have been found to be hosts of the insect, but unfortunately no mention is made of the origin of specific plants and the writers have been unable to trace any of the food plants mentioned in the list to Jamaica origin. The important point is that plants have been brought to Ancon from Jamaica as late as 1912 and undoubtedly later, and Ancon, Balboa, and Panama seem to be the most heavily

and thoroughly infested parts of the Canal Zone and closely adjoining parts of the Republic of Panama. In surveys made by the authors at Ancon, Balboa, and Panama, not a single citrus tree has been found entirely free from *woglumi*, and at least 70 per cent of all the mangoes have been found infested, about 10 per cent of these being heavily infested. Practically all the citrus trees in these towns are limes used for ornamental purposes in gardens, in lawns, or along the streets, and fully 50 per cent of such trees are what might be called heavily infested.

It has also been determined by a survey of the Las Sabanas region, which lies to the north of Panama, that several wealthy Panamanians have themselves introduced plants from Jamaica to that region.

There is no regulation of any kind outside of the ordinary customs regulations governing the introduction of plants to either the Canal Zone or the Republic of Panama from any part of the world. Neither are there any regulations governing the free movement of plants within that area. Hence, it is no uncommon thing to see passengers on vessels from various parts of South America bringing living plants into the Canal Zone or the Republic of Panama, to friends or for their own use. Neither is it an uncommon thing to see passengers from the West Indies or other parts of Central America bringing in plants. These passengers are often residents of the Canal Zone or Republic of Panama and bring the plants as a remembrance of their visit or because of the fact that such plants, if they are fruit trees, bear more delicious fruits than do closely related ones in the Canal Zone or Panama. It is common knowledge that the West Indian negroes are great lovers of plants and it has been repeatedly observed by the writers in their visits to Cristobal that even negro workmen carry plants with them when they leave or arrive in the Canal Zone.

From the foregoing it is apparent that the original infestations of *Aleurocanthus woglumi* occurring at the terminals of the Panama Canal in the Canal Zone and Republic of Panama may be the result of the introduction of more than one lot of infested host plants from Jamaica, and it is probable that the first introduction took place as early as 1912.

Whether the original infestation in the Cristobal-Colon section was a separate introduction or whether it preceded or succeeded the Ancon-Balboa-Panama one will never be known definitely. It must be remembered that the grounds of Ancon Hospital were a sort of botanical garden in the days of the French and remained as such in the early part of the American régime, their place finally being taken by what is now Ancon Nursery. It is quite possible, therefore, that the infested plants might have been sent to Cristobal and Colon from Ancon.

That this insect has been and is freely spread about on citrus nursery stock is shown by the fact that young lime trees in Ancon Nursery were found to be infested with it. Further numerous cases have been found in Panama where persons have grown young citrus trees of various kinds, mostly oranges and tangerines, in the city from seeds and then taken the plants, when they had grown to be a foot or more high, to their farms in the Las Sabanas region or to Taboga Island, which is 12 miles from the mainland in Panama Bay. Indeed, the heavy infestation on this island can not be accounted for in any other way except that infested food plants of the black fly were brought there from the mainland, and from these as a focus the insect has spread by natural means. Unquestionably the infestations at Mount Hope, Gatun, Pedro Miguel, Corozal, and Palo Seco were started in the same way.

At Frijoles and Miraflores the infestations are in all probability "train borne." At the former place lime trees growing by the station and within 25 feet of the railroad track, which were carefully examined in October, 1918, and found to be uninfested, were found slightly infested in April, 1919. In the Canal Zone, the Panama Railroad supplying its commissaries runs its freight cars onto sidings bordered with limes infested with the black fly. This is particularly true at Ancon. Hence adults might readily fly onto or into such freight cars and fly off at a place like Frijoles where practically all trains stop. The only trees found infested in the region were five limes by the station; large oranges and limes around the village, and younger limes at the entrance of the avocado plantation, both of which are at least 150 feet away from the railroad, being free from the pest. The same condition obtained at Miraflores, where two lime trees of a double row of 108 limes leading from the road west of Miraflores Tunnel to the filtration plant were found lightly infested. These trees were the two nearest the railroad and within 75 feet of it. In traveling on the passenger trains from Panama City to various points along the main line, the writers and Mr. Molino have inspected the windows for the adults of *Aleurocanthus woglumi*, and although several species of larger insects have been found, at no time has a single adult of *woglumi* been seen. However, on such trips persons have been seen taking flowers and plants from Colon and Panama to points along the railroad in the Canal Zone or vice versa. The foregoing method may offer a possibility of the introduction of this insect into Florida from Cuba, as Newell (25) has pointed out. Whether the insects could become successfully established depends on the numbers of females that are introduced and whether or not these females have been fertilized. Its successful establishment in Florida will depend also on the adapta-

bility of the insect to climatic conditions that vary considerably from those in which it is now known to occur.

That the spread of this insect in the Ancon-Balboa-Panama, the Cristobal-Colon, the Las Sabanas, and Taboga Island regions is entirely due to the widespread dissemination of infested food plants is not the writers' idea. Doubtless much of the dispersion has been due to this method. But there is sufficient evidence that the infestation does spread to uninfested hosts through the flight or migration of the adults. This has been shown by numerous field-inspection trips. The infestation of large trees such as mango, sapodilla, lime, and orange in these regions, many of them much older than the introduction of *woglumi*, would show this.

At Taboga Island the spread is definitely from the village of Taboga along the shore line to the east and west and to the south following the paths up the steep "backbone" ridge of the island. This spread is most probably a question of the flight of the adults, and the rate at which it is taking place on coffee plants along the creek leading from the village to the south and opposite side of the island substantiates this opinion.

That the adults do fly or migrate is shown by the following facts: There is often a decided variation in the number of adults on the young growth in the morning and evening inspections of the same trees, indicating a migration of the adults either at dusk or in the early morning. On the evening of July 29, 1918, Zetek found several adults in his house, indicating that the migration takes place at dusk; adults have been taken in spider webs 75 to 100 feet away from the nearest infested food plant; the migration from an infested food plant to a noninfested one has been demonstrated in Panama; and finally, the observations at Corozal indicate that a flight of 400 feet is possible. The first point mentioned is shown by the seasonal abundance records for a year, observations on three different lots of trees being made three times a day. Adults caught in spider webs were commonly observed in a garden next to the board of health laboratory during the months of May and June, 1919. Likewise it was found that the adults were flying from heavily infested lime trees to young trees of guayabanon (*Annona squamosa*) and guava (*Psidium guajava*) about 60 feet away and set out in nursery rows. Various stages of the pest were later found on the guava, but the annona here remained free from all stages except the adults.

In the yard of Ignacio Molino in Panama early in April, owing to a heavy infestation of *Aleurocanthus woglumi*, two orange trees were "dehorned," every leaf and green shoot being cut off of them. Early in May, nine new shoots were growing from adventitious buds and on these were found adults of the black fly and egg spirals. A careful survey of all the plants in the yard was made. At a dis-

tance of 30 feet from these orange trees a young palm, *Eleais melanococca*, was found to be lightly infested and adults were seen flying away from it toward the orange trees when disturbed. Hence, it is evident that this palm was the source of reinfestation of the orange.

At Corozal in October, 1918, four lime trees in front of what was once the old post office (house 543, now used as quarters for attendants at Corozal Asylum) were found lightly infested with *A. woglumi*. Across the road, behind the houses opposite Corozal Asylum, on a long open lawn space, was a row of 29 lime trees, none of them infested, the nearest being at least 300 feet from the four infested trees. After the first week of heavy rains following the dry season (Apr. 24, 1919) all trees were reinspected. The infested trees showed a decidedly heavier infestation and of the row of limes uninfested in October, 1918, trees Nos. 9, 10, 20, 25, 27, 28, and 29 were found infested. Tree No. 1 was the farthest away (about 900 feet) from the source of infestation and trees Nos. 20 to 29 the nearest (200 to 300 feet away) to it. Trees Nos. 20 to 25 were almost directly opposite the originally infested trees. That this was a recent infestation was shown by the fact that no individuals were found beyond the pupal stage and no adults had emerged from any of the pupæ found. In July this row of trees was again examined and trees Nos. 9, 10, 11, 12, 18, 20, 23, 25, and 29 were found infested and the infestation was increasing. It is evident that the infestation of numbers 11 and 12 came from trees Nos. 9 and 10 and that of 18 came from tree No. 20. The infestation on Nos. 27 and 28 had died out for some reason. Here we have an infestation due directly to the flight of adults, the longest flight being about 700 feet and the least 200 feet.

It has been noted in bringing adults into the laboratory on shoots on which they had gathered in abundance in the field, that when such shoots wilted the adults would leave them and fly out of the screened windows, a case of forced migration guided by positive phototropism.

Likewise in working around trees on which adults were clustered in the late afternoon it has been observed that when disturbed many of the adults take to flight and, instead of merely flying off a short distance and returning to the trees as they often do, a large number would disappear permanently.

No observations have been made as to whether or not the insect is carried by the wind. Nor has there been seen any such migration as Morrill and Back (21, p. 44-48) have described as taking place in the case of the citrus white fly (*Dialeurodes citri* Ashmead). This is probably due to the fact that no large and heavily infested citrus

groves were available for observation either in the Canal Zone or near-by portions of the Republic of Panama.

Infestations started by adults carried on vehicles or on the clothing of men working among infested trees and then going to unin-fested ones have not been seen. However, the first-mentioned writer, after making observations on trees on which adults were common, has carried stray individuals on his clothing at least 3,000 feet.

The rate of spread or infestation on infested trees has been determined in the following ways: First, taking a shoot that is beginning to grow and watching the number of new spirals laid on the leaves of said shoot; second, taking shoots at the beginning of the rainy season and checking the number of egg spirals laid on the leaves of said shoots. In this latter method shoots of the preceding season were selected and the rate of infestation on this mature growth as well as on new growth that started from the tip of the mature growth was determined by the number of eggs laid on such growth.

The first method is illustrated by the record kept on a young shoot of orange from October 23 to November 17, 1918, or from the time that this shoot had grown from 3.5 to 11 inches long. No eggs were laid before November 5 and the leaves are numbered from the bottom of the growth upward.

TABLE I.—*Number of egg spirals laid by the black fly on young orange shoot.*

Leaf No.	First spirals laid.	Number.	New spirals laid on November—													Total.
			6	7	8	9	10	11	12	13	14	15	16	17		
1	Nov. 5	2	3	1	1	2	2	2	2	2	2	2	2	2	17	
2	Nov. 6	3	3	3	0	1	1	3	1	2	2	2	1	2	17	
3	Nov. 8	3	0	0	3	10	0	0	0	0	2	2	2	2	19	
4	do.	2	0	0	2	5	1	2	2	0	1	1	1	1	11	
5	Nov. 9	4	0	0	0	4	0	2	3	1	4	1	1	1	14	
6	Nov. 12	3	0	0	0	0	0	0	3	4	1	1	1	1	7	
7	Nov. 13	2	0	0	0	0	0	0	0	2	1	1	1	1	2	
8	do.	1	0	0	0	0	0	0	0	1	1	1	1	1	1	
9	Nov. 14	1	0	0	0	0	0	0	0	0	1	1	1	1	1	
10	Nov. 13	1	0	0	0	0	0	0	0	1	1	1	1	1	1	
11	do.	1	0	0	0	0	0	0	0	1	1	1	1	1	0	
12	Nov. 14	1	0	0	0	0	0	0	0	0	1	1	1	1	1	
13	Nov. 15	1	0	0	0	0	0	0	0	0	0	1	1	1	1	

No eggs were laid on this shoot between November 15 and December 1; observations, therefore, were discontinued. In this case it must be borne in mind that the old growth of this tree was heavily infested with *A. woglumi* in all stages of development, and that the adults were abundant on the young growth up until November 17, after which a decided dropping off took place, so that during the period from November 23 to December 23 very few adults were present on the entire tree. On April 8, which is just at the end of the dry season, the eggs on a 19-inch long shoot were counted and found

to be as follows, the count of the leaves being made from the bottom to the top of the shoot.

TABLE II.—*Eggs of black fly on 19-inch orange shoot at end of dry season.*

Leaf No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24.
Egg spirals.	0	0	3	2	1	2	4	1	0	1	5	0	1	2	0	0	0	0	0	0	0	0	0	0.

This shows that the rate of the infestation of young growth on a tree is dependent (1) on the degree of infestation of the older leaves on the tree which, in a large measure, determines the number of adults present on the young growth; (2) on the season. This is discussed further under the heading, "Seasonal history," page 42. For an idea of this tree at the times these counts were made see the photographs (Pl. I).

That the degree of infestation or rate of spread on a given plant is determined by the species of plant is shown by Tables III and IV for the lime trees at Ancon.

TABLE III.—*New egg spirals of the black fly on old and new lime leaves, experiment No. 8, 1919.*

Leaf No.	May 17.	May 24.	May 31.	June 7.	June 14.	June 21.	June 28.	July 5.
1.	0	0	0	0	1	0	0	0
2.	1	0	1	3	1	0	3	2
3.	0	1	2	1	1	0	0	0
4.	0	0	2	0	0	1	0	0
5.	0	0	0	1	1	0	0	0
6.	0	0	3	0	3	(?) 3	4	0
7.	1	1	0	1	0	2	0	0
8.	0	2	0	0	1	1	0	1
A ¹ .	0	1	3	2	2	0	0	2
B.	0	0	0	1	0	2	0	0
C.	0	0	1	0	0	0	0	1
D.	0	0	1	0	1	0	0	0
E.	0	0	1	1	0	0	0	1
Total.	2	5	14	10	11	7	7	7

¹ The leaves on the new growth were lettered A, B, etc., upward from the junction of the new growth with the old and the leaves of the old growth were numbered 1, 2, etc., upward, starting with the junction of a much older shoot or branch.

The observations on this shoot were begun on April 10, 1919, at the end of a dry season, the rainy season beginning on April 13.

TABLE IV.—*New egg spirals of the black fly on old and new lime leaves, experiment 9, 1919.*

Leaf No. ¹	Apr. 17.	Apr. 26.	May 3.	May 10.	May 17.	May 24.	May 31.	June 7.	June 14.	June 21.	June 27. ²
1.	1	1	1	0	0	0	0	2	2	0	1
2.	2	1	0	0	0	1	1	0	7	1	1
3.	0	0	0	0	0	0	1	0	1	1	0
A ³ .					0	0	0	0	0	1	0
B.					0	0	3	1	4	0	0
C.					0	1	0	0	0	1	0
D.					0	0	0	0	0	0	1
E.					0	1	0	0	0	1	0
F.					0	0	0	0	0	0	2
G.					0	1	0	0	0	0	1
H.					0	2	0	0	0	0	1
I.					0	2	0	5	2	0	1
J.					0	1	1	5	1	1	0

¹ In this experiment the lettering of the young growth and the numbering of the old are the same as in the preceding.

² This experiment was accidentally destroyed by the pruning of the trees on June 30.

³ This shoot started to grow on May 3, but no eggs were observed on it until May 24.

These 2 tables are characteristic of 30 that were kept on lime trees. The field observations at Ancon, Balboa, and Cristobal indicate that an infestation of *Aleurocanthus woglumi* on this host, while persistent and oftentimes heavy, does not progress with the rapidity that it does on such hosts as grapefruit, orange, and tangerine. Further discussion of this point is given under "Injury," page 18. In this connection see Plates I, II, and III.

Many of the trees along the roads and on the lawns in Ancon came to the Canal Zone in 1916 as nursery stock from Aguadulce, Republic of Panama, and all those trees are more or less uniformly infested, indicating either that they were all infested at the time that they were set out, or that they became so shortly thereafter through eggs laid on them by migrating adults. It has recently (Sept. 15, 1919) been ascertained, however, through a letter accompanied by specimens, that *Aleurocanthus woglumi* is firmly established at Aguadulce. This would indicate that the trees were infested at the time they were set out, and if the rate at which the infestation on the trees is progressing is any criterion by which to judge the time that *woglumi* has been present in the Canal Zone, it is safe to say that it was first introduced there not later than 1912, for these lime trees must yet, after three years, be regarded as only moderately infested. On this basis and assuming that it came to the Canal Zone during or before 1912, then it has been in Jamaica 15 or more years or at least since before 1910.

In Jamaica and Cuba the insect's spread has paralleled that in the Canal Zone. In the former place after being introduced into the vicinity of Kingston it spread around this locality by both natural and artificial means, but its dispersion to the more distant parts of the island was unquestionably by means of infested food plants. Once it was introduced into a new locality its spread there was by both natural and artificial means. In Cuba it was first introduced into the Guantanamo region on infested plants from Jamaica and its spread took place by both natural and artificial means. From Guantanamo it was carried to Havana on infested plants, where its spread was again by natural and artificial means. Whether or not the infestation in the region of Santiago de la Cuba is a separate introduction of infested plants from Jamaica or whether it is traceable to infested plants from the Guantanamo region is not known.

FOOD PLANTS.

The food plants of the black fly fall under the three following heads: (1) The favorite or preferred food plants, i. e., those that become heavily infested with the insect and on which complete development from egg to adult takes place; (2) the occasional food plants, i. e., those on which complete development of the insect can and does

take place, but which apparently do not become heavily infested with it; (3) supplemental food plants, or those which the adults may visit and from which they may obtain food, but on which either they do not lay eggs or, if they do, complete development does not take place. It must be borne in mind that these three classes are not clear-cut ones but merge into one another. They are based on the writers' observations in the Canal Zone.

In this region the favorite food plants in the order named appear to be *Ardisia revoluta*, the oranges (both sweet and sour), grapefruit, lemon, lime, and mango. No large areas of coffee in infested regions have been found in our surveys and little can be said about this host from our experience, though the writers in Cuba and Jamaica are agreed that it comes before mango in the list.

Among the occasional hosts may be included such plants as sapodilla (*Achras sapota*), oil nut palm (*Eleais melanococca*), Cashew apple (*Anacardium occidentale*), sugar apple (*Annona squamosa*), *Eugenia malaccensis*, mamon (*Melicocca bijuga*), guava (*Psidium guajava*), and mamei (*Lucuma mammosa*). With the exception of the favorite or preferred food plants these constitute an important means by which the insect may be spread on nursery stock or on individual plants. These occasional food plants may and probably will constitute an important source of reinfestation where control of the black fly, especially on citrus, is undertaken. This has been shown in the case of the oil nut palm (*Eleais melanococca*) under the heading "Spread of the insect," on pages 10-11.

Among the supplemental food plants are the orange jessamine (*Chalcas exotica*), Barbados cherry (*Malpighia glabra*), and crape myrtle (*Lagerstroemia indica*). These may serve merely as occasional food plants for the adults or as congregating places, but why the adults should congregate on them in large numbers, even in the presence of their favorite food plants, and not lay eggs, as has been observed in the case of the last two mentioned plants, we will not attempt to explain. That it does not always pay to "jump at conclusions" or to make broad generalizations regarding the food plants of a polyphagous insect like the black fly is shown in the case of the orange jessamine. In the first place, it is a rutaceous plant, a citrus relative, and one would naturally expect it to fall into first or second class of food plants. That it is merely a supplemental host has been proved, not only by the repeated examination of a large number of plants, but also by attempting to rear the insect on it. Never has a single specimen of *Aleurocanthus woglumi* beyond the first instar been found on this plant, though egg spirals are laid in abundance on it and adults often collect in numbers on its younger growth. Although the larvæ are able to attach themselves to the leaves, invariably they die and fall off before reaching the first molt. Hence,

simply because the adults of *woglumi* gather on a plant or because eggs and the early stage larvæ have been found on it, the conclusion that such a plant is an important host of the insect does not necessarily follow. The only criterion as to whether a certain species is in reality a favorite or an occasional food plant is the finding of insects in all stages of development on it.

Aleurocanthus woglumi Ashby has been recorded from 75 different food plants or hosts. These are distributed among 30 plant families.

The following table shows the plants on which it has been found, the family to which the plants belong, and the place and person who collected it. The plants on which it has been found in the Canal Zone and the adjoining parts of the Republic of Panama are marked with an asterisk and a number, the number indicating the class of the food plant as previously discussed. The writers do not presume to say to which class the food plants recorded by other authors belong, but such plants as avocado, hibiscus, various begonias, papaya, croton, plantain, pomegranate, star apple, and coral vine have been repeatedly examined in the Canal Zone and Republic of Panama, and in no case have any stages of the black fly been found on any of them so far. The banana is an example of a plant that is on the border line between the second and third classes. Out of at least a hundred plants that have been carefully examined only three colonies of the insect have ever been found on this host, and those were on a plant growing within 6 feet of a mango heavily infested with the insect.

TABLE V.—*Host plants of the black fly (Aleurocanthus woglumi).*

Scientific botanical name. ¹	Family.	Common name (Spanish and English).	Locality and by whom reported. ²
<i>Acalypha lincolata?</i> (<i>lincolata</i> Willd.).	Euphorbiaceae..	acalypha	Guantanamo, Cuba.—C. J. & H.
<i>Achras sapota</i> Linn. (x-2)...	Sapotaceae.....	nispero, sapote	Canal Zone, Panama, R. P.—D. & Z.
		sapodilla	Cuba (Habana and Guantanamo).—C. J. & H.
<i>Anacardium occidentale</i> Linn. (x-2).	Anacardiaceae..	marañon	Guantanamo, Cuba.—C. J. & H.
<i>Annona chirimola</i> Mill.	Annonaceae.....	cashew apple	Las Sabanas, R. P.—M. & Z.
<i>Annona muricata</i> Linn.	do.....	chirimoya	Guantanamo, Cuba.—C. J. & H.
		Jamaica apple.....	Do.
		anon manteca	Guantanamo, Cuba.—C. J. & H.
		soursop	Do.
<i>Annona squamosa</i> Linn. (x-2).	do.....	anon	Guantanamo, Cuba.—C. J. & H.
<i>Annona</i> sp. (x-2)	do.....	sugar apple, sweetsop...	Las Sabanas, R. P.—M. & Z.
			Canal Zone.—D. & M.
<i>Antigonon leptopus</i> Hook...	Polygonaceae.....	rosa de montaña, coralito.	Guantanamo, Cuba.—C. J. & H.
<i>Ardisia revoluta</i> H. B. & K. (x-1).	Myrsinaceae.....	coral vine, love's chain.	Do.
<i>Bassia latifolia</i> Roxb.	Sapotaceae.....	fruta de pava	Las Sabanas, R. P.—M. & Z.
<i>Begonia</i> sp.	Begoniaceae.....		Jamaica.—R.
			Guantanamo, Cuba.—C. J. & H.
<i>Capparis pedunculosa</i> Wall..	Capparidaceae...	caper-bush	Royal Botanical Garden, Ceylon.—W. Q. & B.
<i>Capparis roxburghi</i> DC.	do.....	do.....	Do.
<i>Carica papaya</i> Linn.	Papayaceae.....	fruta bomba, papaya...	Guantanamo, Cuba.—C. J. & H.
		papaya	Do.

For footnotes 1 and 2 see page 18.

TABLE V.—Host plants of the black fly (*Aleurocanthus woglumi*)—Continued.

Scientific botanical name.	Family.	Common name (Spanish and English).	Locality and by whom reported.*
<i>Cestrum diurnum</i> Linn.....	Solanaceae.....	galan de dia..... day-blooming jessamine.	Guantanamo, Cuba.—C. J. & H.
<i>Cestrum nocturnum</i> Linn.....	do.....	galan de noche..... night-blooming jessamine.	Do. Jamaica.—A. Q. & B.
<i>Chalcas exotica</i> Millsp. (x-3).	Rutaceae.....	orange jessamine.....	Canal Zone and Panama, R. P.—D. & Z.
<i>Chrysophyllum cainito</i> Linn.	Sapotaceae.....	star apple.....	Guantanamo, Cuba.—H.
<i>Citrus aurantifolia</i> Swingle (<i>limetta</i> auct.) (x-1).	} Rutaceae.....	lima..... lime.....	Canal Zone, Panama, and Taboga, R. P.—D. & Z. Cuba (Guantanamo and Habana).—C. J. & H.
<i>Citrus aurantium</i> Linn. (x-1)		naranzo..... sour orange.....	Canal Zone, Panama, R. P. ?—D. & Z. Cuba (Guantanamo and Habana).—C. J. & H.
<i>Citrus grandis</i> Osbeck (<i>decumana</i> Linn.) (x-1).	} do.....	toronja..... grapefruit.....	Canal Zone, Panama, and Taboga, R. P.—D. & Z. Cuba (Guantanamo and Habana).—C. J. & H.
<i>Citrus limonia</i> Osbeck (x-1).		limon, limonero..... lemon.....	Canal Zone ?, Panama, R. P.—D. & Z. Cuba (Habana and Guantanamo).—C. J. & H.
<i>Citrus medica</i> Linn.....	do.....	cidro..... citron.....	Cuba (Guantanamo and Habana).—C. J. & H.
<i>Citrus nobilis deliciosa</i> Swingle (x-1).	} do.....	tangerino..... tangerine.....	Panama, R. P.—D. & Z. Santiago, Cuba.—Mann.
<i>Citrus sinensis</i> Osbeck (x-1).		naranzo..... sweet orange.....	Canal Zone, Panama, and Taboga, R. P.—D. & Z.
<i>Citrus</i> spp.....	do.....	not specified.....	Jamaica.—A. Q. & B. India (Lahore, Gujranwala, Kalimpong, Sikkim, Nagpur) (C. P.).—W. Q. & B.
<i>Citrus</i> sp. not specified.....	do.....	orange.....	India.—M. Q. & B., Manila, P. I.—Comp. Q. & B., Nassau, N. P. Bahama.—Brace, Q. & B. Cuba, Santiago.—Mann.
<i>Citrus</i> sp. not specified.....	do.....	lemon.....	Santiago, Cuba.—Mann.
<i>Clausena lansium</i> Skeels (<i>Clausena wampi</i> Oliv.).	do.....	wampee.....	Jamaica.—R.
<i>Coffea arabica</i> Linn. (x-1)	Rubiaceae.....	cafeito..... coffee.....	Cuba (Guantanamo and Habana).—C. J. & H. Jamaica.—A. & R., Taboga, R. P.—D. & Z. Las Sabanas, R. P.—M. & Z.
<i>Cordia alba</i> Roem. and Schult.	} Boraginaceae.....	uvita o goma..... cordia.....	Cuba (Guantanamo).—C. J. & H.
<i>Cordia</i> sp.....		do.....	Do.
<i>Crescentia cujete</i> Linn.....	Bignoniaceae.....	guira..... calabash, gourd tree.....	Do.
<i>Croton</i> sp., probably <i>Codiaeum</i> referred to.	} Euphorbiaceae.....	croton..... croton.....	Do.
<i>Cupania cubensis</i> (Blighia sapida Kon.)		quarana.....	Do.
<i>Eleais melanococca</i> Gaertn. (x-2).	Palmaceae.....	akee..... oil nut palm.....	Panama, R. P., Cristobal, C. Z.—D. & M.
<i>Eugenia jambos</i> Linn. (x-2).	Myrtaceae.....	pomaroza..... rose apple.....	Las Sabanas, R. P.—M. & Z.
<i>Eugenia malaccensis</i> Linn. (x-1 or 2).	do.....	manzana de Tahiti..... large-fruited rose apple.....	Do.
<i>Guaiacum officinale</i> Linn.....	Zygophyllaceae.....	lignum-vitae.....	Jamaica.—A.
<i>Guazuma tomentosa</i> Knuth.	Sterculiaceae.....	guasima, guacima.....	Cuba (Guantanamo).—C. J. & H.
<i>Hibiscus rosa-chinensis</i> Linn.	Malvaceae.....	Chinese hibiscus.....	Do.
<i>Hibiscus schizopetalus</i> Hook.	do.....	farolito chino..... hibiscus.....	Do.
<i>Ilex thea</i> Hook (x-3).	Rubiaceae.....	bouquet de novia.....	Canal Zone.—D. & M.
<i>Kurrimia ceylanica</i> Arn.....	Celastraceae.....		Peradeniya, Ceylon.—Ruth. Q. & B.
<i>Laurus nobilis</i> Linn.....	Lauraceae.....	laurel comun..... laurel, sweet bay.....	Cuba (Guantanamo).—C. J. & H.
<i>Lagerstroemia indica</i> Linn. (x-3).	Lythraceae.....	crape myrtle.....	Canal Zone, Las Sabanas, R. P.—D. & M.
<i>Lucuma mammosa</i> Gaertn. (x-2).	} Sapotaceae.....	mamey, mamey de tierra, mamei..... mamei, mamey sapote.....	Cuba (Guantanamo and Habana).—C. J. & H. Las Sabanas, R. P.—M. & Z.
<i>Lucuma nervosa</i> A. DC. (x-2).		canistel..... egg-fruit, canistel.....	Do.

For footnotes 1 and 2 see page 18.

TABLE V.—*Host plants of the black fly (Aleurocanthus woglumi)*—Continued.

Scientific botanical name. ¹	Family.	Common name (Spanish and English).	Locality and by whom reported. ²
<i>Malpighia glabra</i> Linn. (x-3)	Malpighiaceae...	{cereza. Barbados cherry.....	{Cuba (Guantanamo and Habana).—C. J. & H. Las Sabanas, R. P.—M. & Z.
<i>Melicocca bijuga</i> Linn. (x-2)	Sapindaceae....	{mamoncillo, mamon... {Spanish lime.....	{Cuba (Guantanamo and Habana).—C. J. & H. Las Sabanas, R. P.—M. & Z.
<i>Mangifera indica</i> Linn. (x-1)	Anacardiaceae...	{mango. mango.....	{Canal Zone, Panama, Colon, Taboga, R. P.—D. & Z. Cuba (Guantanamo and Habana).—C. J. & H. Santiago, Mann; Jamaica.—A. & R. Lahore, India.—W. Q. & B.
<i>Morus</i> sp.....	Moraceae.....	mulberry.....	Cuba (Guantanamo).—C. J. & H.
<i>Musa paradisiaca</i> Linn.....	{Scitamineaceae (Musaceae).....	platano macho.....	{Cuba (Guantanamo).—C. J. & H.
<i>Musa sapientum</i> Linn. (x-2)	do.....	{guineo..... banana.....	{Canal Zone.—D. Z. & M.
<i>Passiflora edulis</i> Sims, probably referring to <i>P. quadrangularis</i> Linn. as well).	{Passifloraceae.....	{granadillo..... maypop, passion flower..	{Cuba (Guantanamo).—C. J. & H.
<i>Persea gratissima</i> Gaertn....		{aguacate..... avocado, alligator pear..	{Cuba (Guantanamo and Habana).—C. J. & H.
<i>Psidium guajava</i> Linn (x-2)	Myrtaceae.....	{guayabo, guayaba..... guava.....	{Cuba (Guantanamo and Habana).—C. J. & H. Canal Zone, Las Sabanas.—D. & M.
<i>Punica granatum</i> Linn.....	Punicaceae.....	{granado..... pomegranate.....	{Cuba (Guantanamo and Habana).—C. J. & H.
<i>Salacia reticulata</i> Wight....	Celastraceae.....	.....	Ceylon (Peradeniya).—Ruth, Q. & B.
<i>Tabernaemontana coronaria</i> Willd.	{Apocynaceae.....	{jasmin de montaña..... crape jasmine, E. Indian rosebay.....	{Cuba (Guantanamo).—C. J. & H.
<i>Triphasia aurantiola</i> Lour..		limoncillo.....	Cuba (Guantanamo and Habana).—C. J. & H.
<i>Trichilia spondioides</i> Jacq...	Meliaceae.....	jubaban.....	Cuba (Guantanamo).—C. J. & H.
<i>Wallenia laurifolia</i> Sw.....	Myrsinaceae.....	casmagua.....	Cuba (Guantanamo and Habana).—C. J. & H.
Plants of uncertain identity.		{jasmin de candelero..... jasmine..... jasmin de Persia..... jasmine.....	{Cuba (Guantanamo).—C. J. & H. Do.
		manzana de rosa.....	Cuba (Guantanamo and Habana).—C. J. & H.
		rose apple?.....	Cuba (Guantanamo).—C. J. & H.
		palma de abanico.....	Cuba (Guantanamo).—C. J. & H.
		travelers' palm.....	Il.
		unknown tree.....	India.—W. Q. & B.

¹ KEY TO NUMBERS.

x-1, x-2, and x-3 refer to the class to which the food plant belongs, x-1 being favorite or preferred food plant, x-2 occasional food plant, and x-3 supplemental food plant, for a discussion of which see text, p. 14-18.

² KEY TO INITIALS.

- A.—Ashby, S. F.
 A. Q. & B.—Ashby, S. F., Quaintance, A. L., and Baker, A. C.
 B.—Brace, Q. & B.—Brace, L. J. K., Quaintance, A. L., and Baker, A. C. C. J. & H.—Cardin, Patricio; Johnston, J. R., and Hutson, J. C.
 C.—Comp. Q. & B.—Compere, George, Quaintance, A. L., and Baker, A. C. D. & M.—Dietz, H. F., and Molino, Ignacio. D. & Z.—Dietz, H. F., and Zetek, James. Mann.—Mann, W. M.
 M. Q. & B.—Maxwell-Lefroy, Quaintance, A. L., and Baker, A. C. M. & Z.—Molino, Ignacio, and Zetek, James. R.—Ritchie, Archibald H.
 R. Q. & B.—Rutherford, A., Quaintance, A. L., and Baker, A. C.
 W. Q. & B.—Woglum, R. S., Quaintance, A. L., and Baker, A. C.
 In the report of the hosts credited to Quaintance and Baker the first named person in every case refers to the collector of the material.

INJURY.

Much has been written about the injury caused by the black fly to its favorite or preferred food plants. It has also been said that it only takes 20 months for this insect to increase to such numbers that it will kill its hosts, and "that an infestation of the black fly is invariably accompanied by rapidly-increasing scale infestation so that the life of an infested tree is necessarily short" (25). Furthermore, it

has been intimated by some writers that the black fly is an insect that can not be controlled except by such radical measures as were of necessity used in the eradication of citrus canker.

Careful attention, therefore, was given this phase of the problem by the writers. In order to determine definitely the amount of injury done, numerous inspections and reinspections of trees were made. Daily observations were made for a year on a row of lime trees, and the condition of these trees in October, 1918, and April, 1919, is shown in Plate II, figure 2, and Plate III, figure 2. Plate III, figure 1, shows the degree of infestation, which seemed to be at more or less of a standstill throughout this time, and there was practically no development of the black fly on these trees during the dry season. No appreciable injury was done to the trees during the year from June, 1918, to June, 1919.

As a check on these lime trees an equal number growing thickly together in a hillside garden near the Board of Health laboratory was selected. Plates V and VI show the degree of infestation and here, because the trees were kept well shaded and protected from the drying winds by a large guava and were well watered at all times during the dry season, there seemed to be no checking of the development of the black fly at any time.

However, while these trees showed some injury, i. e., a dropping of perhaps 5 to 10 per cent of their total number of leaves, they were far from being killed. Neither did the infestation of *woglumi* seriously interfere with the production of fruit on them. The infestation, however, rendered the trees extremely unsightly. These trees, like those in Plate II, figure 2, and Plate III, figure 2, put forth an abundance of young growth with the coming of the wet season (from the middle of April to the last of June), and seemed to be outgrowing the *woglumi* infestation.

In contrast with these two groups of limes is the young orange tree shown in Plate I. This is one of the few trees of this species that were readily accessible for daily observation. The degree of infestation in October, 1918, is shown in Plate I, A, and Pl. IV, fig. 1. By the end of November, 1918, the infestation was very severe, the underside of every leaf being a mass of eggs and individuals in all stages of development. On the younger leaves it was estimated from counts that there were between 3,500 and 4,000 eggs per leaf, and when these began hatching the undersides were black with larvæ just as if they had been dusted with soot. Due to this overcrowding on the part of the insects on the leaves there was unquestionably a heavy drain on the sap supply of the tree and when the dry season set in during the latter part of December, the tree began shedding its leaves, in spite of the fact that it was watered daily. The following is the apparent explanation of this defoliation: During the dry season

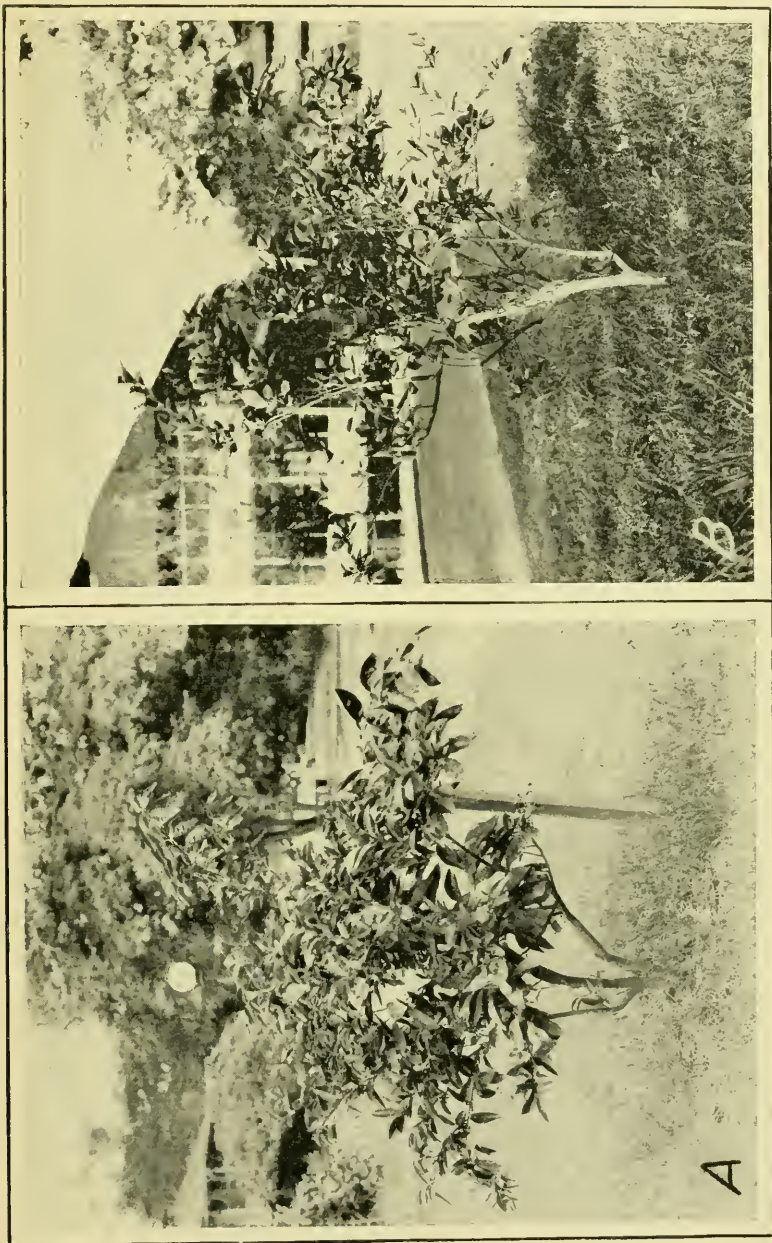
in the Canal Zone there is always a steady breeze blowing which naturally increases transpiration from the leaves. This increased transpiration, coupled with the drain on the sap supply due to the insects, caused the wilting and subsequent dropping of the leaves so that by April, 1919 (the end of the dry season) (Pl. I, B), fully 75 per cent of the total number of leaves were lost. This loss of leaves, however, seemed to be a benefit to the tree, for when a leaf wilted it checked the development of all stages of the black fly occurring on it and when it fell large numbers of the insects were killed, as is shown by experiments on the effects of drying on the emergence both of larvæ from eggs and of adults from pupæ. Likewise, the rate of reinfestation from April to September, 1919, has been very slow, due to the fact that practically all heavily-infested leaves were shed. But this tree is far from being dead, and with the coming of the wet season in the middle of April, it put forth an abundance of new growth, the greater part of which was free from *woglumi*, so that one not knowing its previous history would scarcely suspect that it had been one of the most heavily-infested trees found in the Canal Zone.

The observations on this tree were checked against those made on both orange and tangerine trees heavily infested with *A. woglumi* in the Las Sabanas region of Panama. Here the trees were unwatered, but the fact that they were of considerable size, close together, and protected by windbreaks, offsets this factor. The percentage of leaves lost was not as great as in the case of the tree at Ancon, due no doubt to a checking of the development of the black fly during the dry season so that the infestation at the end of the dry season was noticeably less than at the beginning. There was nothing here to indicate that either the quantity or quality of the fruit had been seriously reduced by the black fly.

In several instances in the outlying parts of the Las Sabanas region various kinds of citrus that were well cared for, but received water only at long intervals or not at all, were found to be in a badly wilted condition, but examination showed them to be entirely free from *woglumi*. Such trees, however, seemed able to resist the drought much better than infested ones and did not lose as large a percentage of leaves. On the other hand, trees in the same region and likewise uninfested but neglected in every way were found to be decidedly dwarfed in size and many were dead and dying. These same conditions were verified in the Canal Zone.

In the village of Taboga on the island of that name, lime trees growing under very adverse conditions and heavily infested showed some injury but not as much as might have been expected.

At Frijoles and Corozal dead and dying lime trees were found. At the first place neither scale insects nor the black fly were present,



THE BLACK FLY.

Young orange trees at Ancon, Canal Zone, kept under daily observation for over a year. A, Photographed in October, 1918; B, photographed in April, 1919, shortly after the beginning of the rainy season. Note the defoliation due to a heavy infestation of *Alurocandus woytami*, and compare with Plate IV, figure 1.



FIG. 1.—INFESTED LIME LEAVES, SHOWING VARIOUS STAGES OF DEVELOPMENT OF INFESTATION.

These leaves were taken from trees shown in figure 2.



FIG. 2.—YOUNG LIME TREES MODERATELY INFESTED THAT WERE KEPT UNDER DAILY OBSERVATION FOR OVER A YEAR. PHOTOGRAPHED IN OCTOBER, 1918.
THE BLACK FLY.

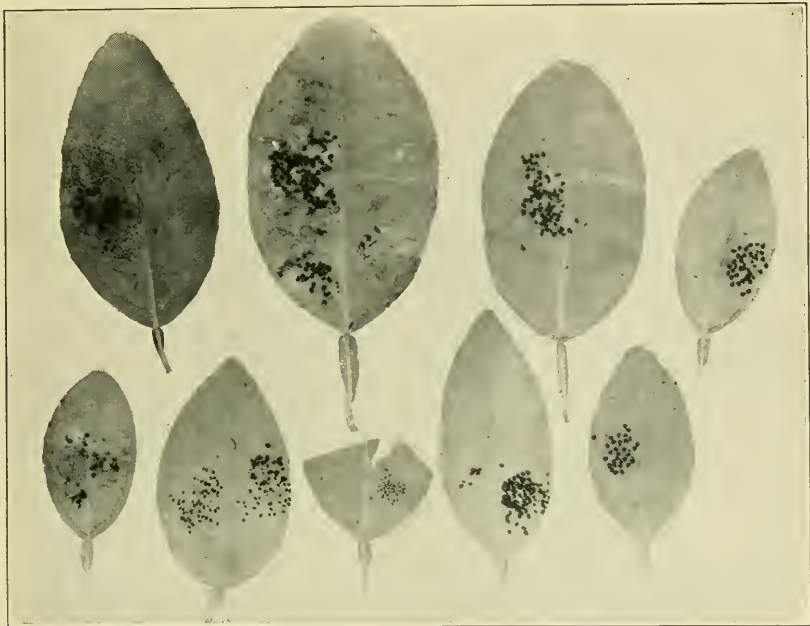


FIG. 1.—INFESTED LIME LEAVES TAKEN FROM TREES SHOWN IN FIGURE 2, IN MAY, 1919. COMPARE WITH PLATE II, FIGURE 1.

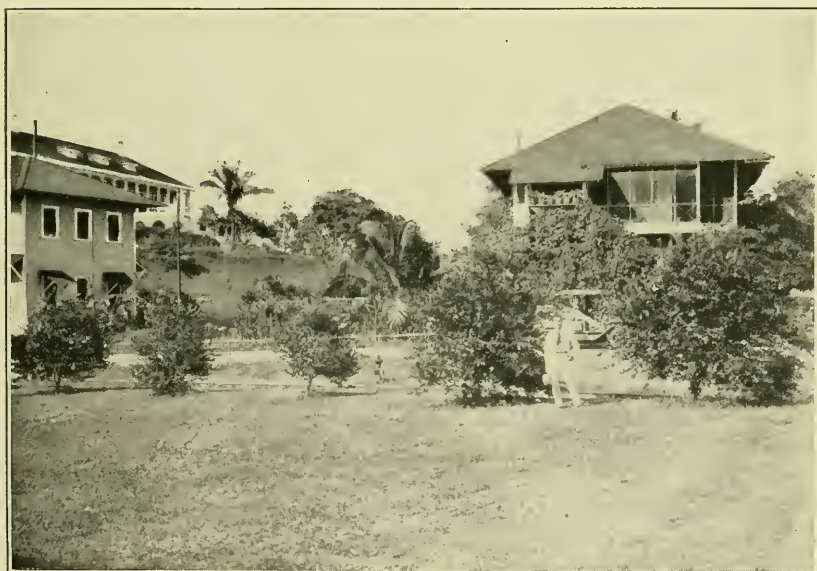


FIG. 2.—THE SAME TREES SHOWN IN PLATE II, FIGURE 2, PHOTOGRAPHED IN APRIL, 1919, SHORTLY AFTER THE BEGINNING OF THE RAINY SEASON.

Note the vigorous growth.

THE BLACK FLY.



FIG. 1.—INFESTED ORANGE LEAVES FROM TREE SHOWN IN PLATE I. TAKEN IN OCTOBER, 1918.

In April, 1919, due to heavy shedding of infested leaves during the dry season, the tree was only lightly infested.

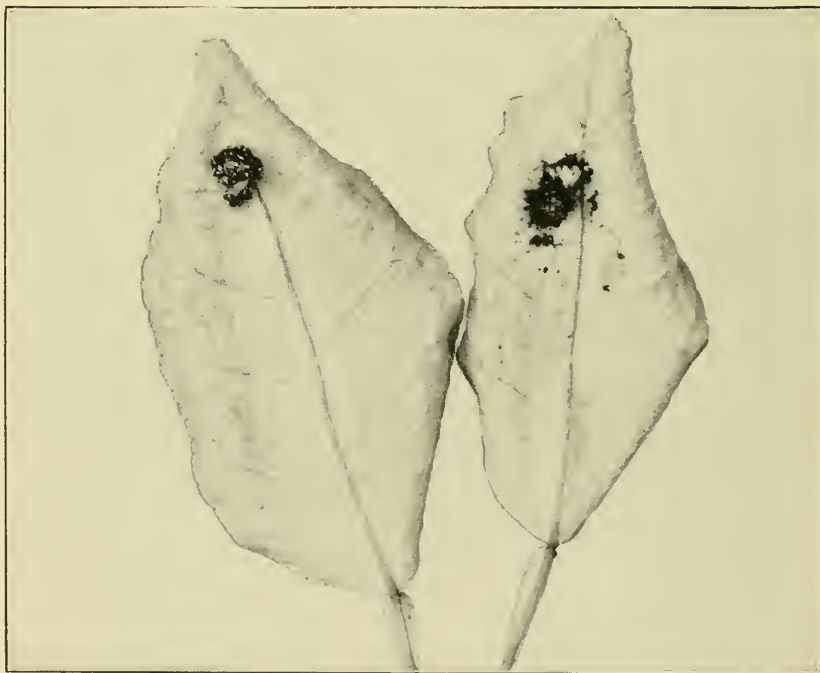


FIG. 2.—PUPA CASES OF *CHRYSOPE* SP., THE LARVÆ OF WHICH ARE PREDATORY ON ALL STAGES OF *ALEUROCANTHUS WOGLUMI*.

Note the masses of empty skins of the victims.

THE BLACK FLY.



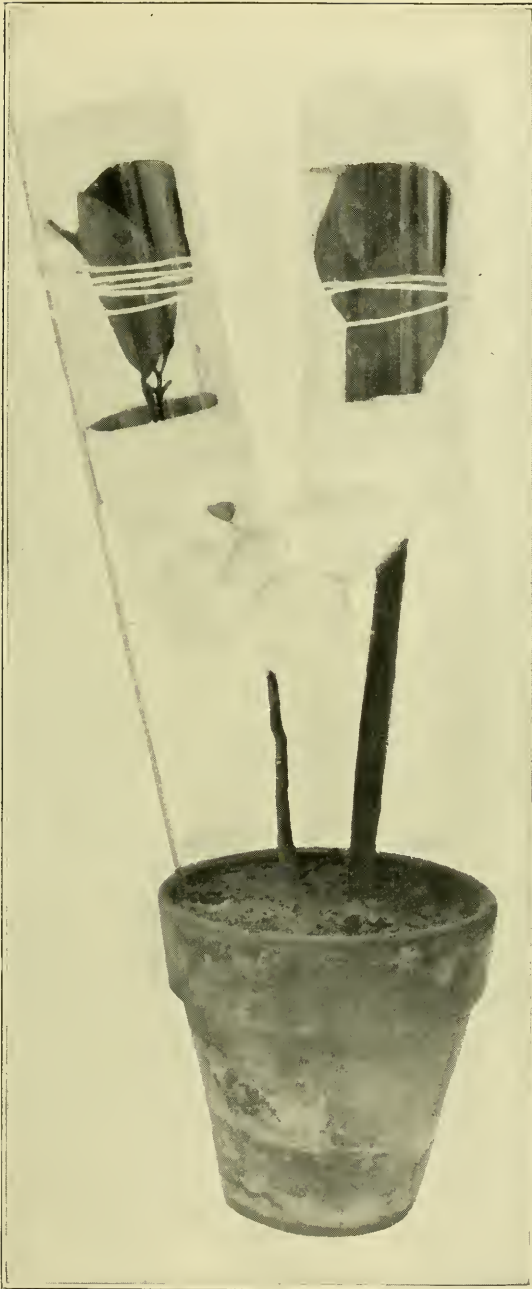
THE BLACK FLY

Leaves from heavily infested lime trees coated with "sooty mold" growing on the honeydew excreted by the insect.



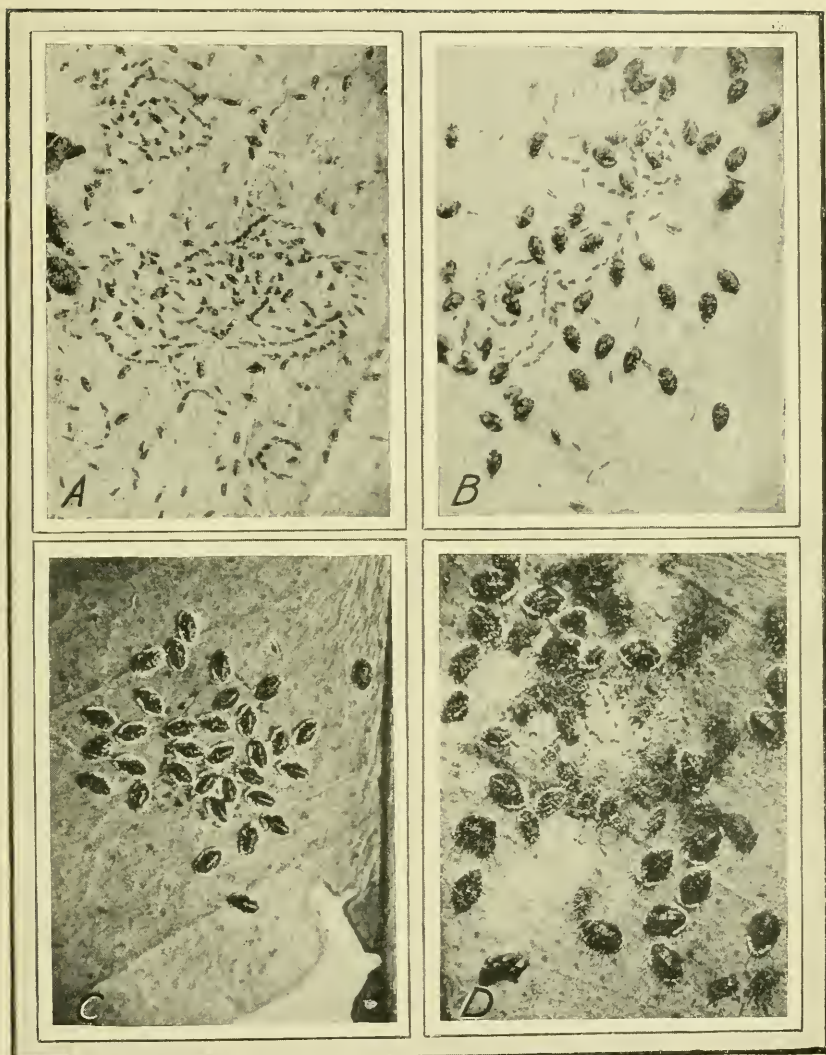
THE BLACK FLY.

The undersurface of the same shoot shown in Plate V.



THE BLACK FLY.

Celluloid cages in which adults were confined in order to obtain egg spirals for observation.



STAGES IN THE LIFE HISTORY OF THE BLACK FLY.

A, Eggs and first and second instar larvæ; B, eggs and third instar larvæ; C, male pupæ; D, female pupæ. All enlarged to the same scale (taken with 48 mm. lens).

but the injury seemed to be due to neglect and to the fungus (*Gloeosporium gloeosporoides*), which had gained entrance to the trees through pruning wounds. At Corozal the injury seemed to be due to heavy infestations of the purple scale (*Lepidosaphes beckii* Newm.), and of the West Indian red scale [*Pseudaonidia* (*Selenaspides*) *articulatus* Morg.]. These dying lime trees were not heavily infested with *A. woglumi*.

In the authors' work at Ancon, Balboa, and Cristobal, it was found that when citrus trees (lime, orange, and grapefruit) were heavily infested with the two scales mentioned above, they were almost invariably only lightly infested with *A. woglumi* even though they were in close proximity to trees heavily infested with this insect. From the authors' experience then it would seem that the infestations of scale insects and the black fly go on independently of each other and it does not necessarily follow "that an infestation of the black fly is invariably accompanied by rapidly increasing scale infestations so that the life of an infested tree is necessarily short" (25). That this may take place is not denied, but that it has not taken place in the Canal Zone to date is the result of a year's observation in that region. It has also been observed that heavy infestations, especially of the West Indian red scale, serve as a decided inhibition to the development of the black fly, as will be pointed out under the life history of the insect. The writers find that the two scales mentioned do far more actual and noticeable damage than the black fly in that they actually kill infested areas on the leaves and cause infested twigs to die. In many instances the cultural conditions and neglect to which trees have been subjected are in themselves sufficient to injure them seriously even if no insect or fungous pests were involved and such factors coupled with a heavy infestation of the black fly doubtless will, in time, prove a handicap that these trees will be unable to overcome in spite of the fact that the climatological conditions of this region are extremely favorable to plant development.

Since in all the survey work conducted by the authors a tree was never found killed by the black fly, it is safe to conclude that much of its injury is "ornamental" and that the fact that it makes heavily infested trees decidedly unsightly has been largely responsible for the exaggerated statements regarding its destructiveness.

In conclusion the authors' work bears out the following statements of Morrison, who has seen the insect and its injury in the Canal Zone, Jamaica, and Cuba: "It may be said that the presence of this pest in numbers affects adversely the infested tree, and may in cases where other factors are also unfavorable be the final handicap which prevents the production of a crop of fruit or reduces it in size until it is unprofitable commercially to grow such a crop, or prevents the trees from making the amount of new growth each year which is necessary

to their proper development. There is nothing to indicate that, if it succeeded in entering the United States, it would prove to be an almost hopeless case * * * though it would without question prove to be a heavy additional load for citrus growers already burdened with numerous other injurious insects and diseases."

LIFE HISTORY AND HABITS.

In this work certain difficulties due to the habits of the adults of *A. woglumi* had to be overcome. These habits made it impossible, in many instances, to secure much desired data by the direct method. The data desired were the number of eggs laid by a single female; whether unfertilized females lay only eggs that give rise to males; how soon after emergence copulation takes place; the length of life of the adults; and how soon after emergence egg-laying begins. The difficulty of finding out these facts by the direct method, namely, by taking individuals of known history and confining them with leaves in cages (Pl. VII) or in petri dishes, was due to the nervousness of the adults when they were disturbed or handled. Whether adults were confined singly or in numbers seemed to make little difference. Once they were disturbed and confined, they would worry themselves to death in their attempts to escape and instead of resting on the leaves of the plant to which they were confined they would wander up and down the sides of the cage. Often pupæ from which adults were ready to emerge were placed in petri dishes with fresh leaves, but almost invariably on emergence the adults, after becoming thoroughly colored, would begin wandering around the cage in their attempts to get away. In no case did adults obtained in this way live over four days. Therefore, another and less accurate method of observing the habits of the adults and obtaining spirals for life-history work had to be adopted. Large numbers of males and females were brought into the laboratory on the young shoots on which they were found resting in the field. Copulation was usually in progress and this insured obtaining normal fertilized eggs. These shoots were placed in water and as they wilted the males and females would leave them. Therefore, such shoots were set among young trees so that the adults could congregate on these. For a time this method was successful, but it often failed, apparently due to the fact that the females preferred to lay eggs on the wilted leaves rather than on those of the trees that were provided. This may have been due to the age of the leaves on the trees, but no such pronounced selection on the part of the females in the field has been observed. In the field, spirals which from their color and from actual observation were known to have just been laid were used. Those were chosen that occurred alone on the leaves, or if any other spirals happened to be laid on the same leaf, which was rarely the case,

these were removed. The chosen spirals were observed daily, or three times daily in many instances, until the life cycle was complete. Hence by close observations in the field and by a careful study of the habits of the insects in all stages in the laboratory, answers to most of the questions mentioned before, and which could not be determined by the direct method, have been obtained.

Two methods were used in obtaining the life history of this insect, namely, the group method and the individual method. Both had certain advantages and disadvantages. The group method consisted in taking an egg spiral laid on a known date, watching for the eggs to hatch, and then making observations on the individuals from one to three times daily until they had completed their life cycle. In this case, however, only the number of individuals that passed from one instar to another on a given date was recorded day by day. The individual method consisted in accurately plotting the egg spiral and the position of the larvæ after they had settled and giving each one a number to be retained by it throughout its development. The time when each molted was then recorded, thus giving a very accurate record of the development of each individual. The advantage of the group method is that it is a rapid one and shows readily by a glance at the chart how many individuals die in a given instar, the duration of a given molt, and the time of the maximum molting for a given molt. (See fig. 5.) From such a chart the life-history curve of the individuals of one lot of eggs can be plotted directly. The great objection to this method is that it does not give a clear-cut individual record, which is also desirable. The advantages and disadvantages of the individual records are just the inverse of the group record, but the chief objection in the work here was that this method was too slow and there was in many cases a waste of time due to the great mortality of *A. woglumi*, especially in the first instar, as will be shown later. The two kinds of records taken together make an ideal combination, as one can be used to interpret the other.

The following tables are representative of the two methods of recording the life history and show the range and variation under favorable (field) conditions and more or less unfavorable (laboratory) conditions. In the laboratory the small trees used were watered daily, but the humidity was often as much as 20 per cent lower indoors than out-of-doors, and there was generally a considerable breeze blowing through the room. Likewise the light in the room was dull and it seems that all the factors taken together retarded the individuals, especially in the pupal stage. But laboratory data give a clue to the ability of the species to adapt itself to its environment and likewise indicate what takes place in the dry season, especially in a region like Las Sabanas.

It is seen, therefore, that Ashby (3) is right fundamentally regarding the life history of the black fly. But he did not go far enough in his studies. The life history is not clear-cut, as one is led to believe from his brief work, and is greatly influenced by conditions. The total length of time from the egg to the adult as given by him and Cardin (11) may be much longer than they indicate. Some of the individuals do go through their development in as few as 55 days, but there is a great variation and the majority take a



FIG. 5.—Diagrammatic chart showing method used in keeping record of individuals of *Aleurocanthus woglumi* in life-history work.

longer time, especially under unfavorable conditions. There is considerable variation in the length of time that individuals remain in each instar, the greatest variation being in the time that they remain in the pupal stage. This is true in a colony all of whose individuals hatched from the same egg spiral. There seems to be a constant dropping back of some individuals so that the group life history is drawn out.

The time for the complete development from egg to adult, as is shown by the tables, ranges from 55 (45 the minimum) to 113 (the maximum) days.

TABLE VI.—*Life history of Aleurocanthus woglumi.*

GROUP RECORD 2 (1918), INDOOR EXPERIMENT. HOST: LIME.

Eggs laid.	No.	Hatched.	No.	First molt.	No.	Second molt.	No.	Thrd molt.	No.	Adults.	No.	Sex. ¹	
												M.	F.
Aug. 6 ¹	55	Aug. 17 Aug. 18 Aug. 19	30 20 5	Aug. 25 Aug. 26 ³	30 17	Sept. 1 Sept. 2 Sept. 3 Sept. 4 ⁴	6 9 17 2	Sept. 10 Sept. 11 Sept. 12 Sept. 13 Sept. 14 ⁵	2 9 6 5 2	Oct. 7 Oct. 8 Oct. 11 Oct. 12 Oct. 15 Oct. 23 Oct. 24 Oct. 31 Nov. 1 Nov. 5 Nov. 12 ⁶	2 1 1 1 1 1 1 2 1 1	.....	.....
Total.....	55	.....	55	.....	47	.....	34	.....	24	.....	13	13	.....

GROUP RECORD 4 (1918), INDOOR EXPERIMENT. HOST: LIME.

Sept. 26.....	38	Oct. 10 Oct. 14 Oct. 15 ⁸	27 1 5	Oct. 17 ⁷ Oct. 18 Oct. 19 Oct. 20 Oct. 21 Oct. 22 ¹¹	4 1 3 1 3 2	Oct. 25 Oct. 27 Oct. 28 Oct. 30 Oct. 31 Nov. 1 ¹²	1 1 1 1 1 3	Nov. 5 Nov. 6 Nov. 12 Nov. 15 ⁹	1 1 3 2	Nov. 26 Dec. 2 Dec. 8 Dec. 10 Dec. 14 ¹⁰	1 1 1 1 1	.....	1
Total.....	38	.....	33	.....	14	.....	8	.....	7	.....	5	2	3

GROUP RECORD 32 (1919), OUT-OF-DOORS EXPERIMENT. HOST: LIME.

May 11.....	20	May 24 May 25 May 27 ¹³	11 3 4	June 2 June 3 June 4 ¹⁴	14 3 1	June 7 June 8 June 9 June 10 June 11 June 12	6 0 6 2 1 1	June 18 June 19 June 20 June 21	5 5 1 5	July 5 July 6 July 9 July 10 July 11 July 12	4 2 1 3 3 3	4 .....	.....
Total.....	20	.....	18	.....	16	.....	16	.....	16	.....	16	6	10

GROUP RECORD 36 (1919), OUT-OF-DOORS EXPERIMENT. HOST: ORANGE.

May 12.....	48	May 24 ¹⁵ May 25 May 26	11 13 20	June 2 June 3 June 4 June 5 ¹⁷ June 6 ¹⁷	8 2 1 0 2	June 7 ¹⁶ June 8 June 9 June 10 June 11	2 0 5 1 1	June 15 June 16 June 17 June 18 June 19	2 3 1 1 2	July 4 July 5 July 6 July 7 July 8 July 10	2 3 1 1 1 1	.....	2
Total.....	48	.....	44	.....	13	.....	9	.....	9	.....	9	4	5

¹ All males.² Laid by unfertilized female.³ Eight first larval instar individuals dropped off while molting.⁴ Four second larval instar individuals died in this stage. Nine fell off.⁵ Ten third larval instar individuals died in this stage.⁶ Leaf fell on Dec. 28, 1918, without further emergence from 9 pupæ that were left. Two fell off.⁷ Ten first larval instar individuals lost in molting.⁸ Three eggs failed to hatch and 2 first larval individuals were lost.⁹ One third larval instar individual died in this stage.¹⁰ Leaf fell Dec. 24, 1918, without emergence from 1 male and 1 female pupa.¹¹ Nine first larval instar individuals died in this stage.¹² Six second larval instar individuals died in this stage.¹³ Eggs all hatched; two first larval instar individuals fell off before settling down.¹⁴ Two first larval instar individuals fell off in molting.¹⁵ All eggs hatched; 4 first larval instar individuals fell off before settling down.¹⁶ See ¹⁷, 4 second larval instar individuals washed off.¹⁷ On June 5 and 6, 31 first larval instar individuals and 4 second larval instar individuals were washed off by heavy rains at molting time.

TABLE VI.—*Life history of Aleurocanthus woglumi*—Continued.

GROUP RECORD 42 (1919), OUT-OF-DOORS EXPERIMENT. HOST: ORANGE.

Eggs laid.	No.	Hatched.	No.	First molt.	No.	Second molt.	No.	Third molt.	No.	Adults.	No.	Sex.	
												M.	F.
May 15.....	32	May 27 May 28 May 29 May 30 May 31 June 1 ¹⁸	6 0 3 0 10 12	June 3 June 4 June 5 June 6 June 7 June 8 ¹⁹	5 5 6 2 6 5	June 10 June 11 June 12 June 13 June 14 June 15	1 1 2 8 2 3	June 19 June 20 June 21 June 22 June 23 June 24- June 29	1 0 2 4 2 5	July 12 July 14 July 15 July 16 July 17 July 18	3 1 1 3 1 1	3 1	 1 3 1 1
						June 16 June 17- June 18 June 19 ²⁰	6 0 1 1	June 30 July 1 July 2-4 July 5 ²¹	2 2 0 1	July 21 July 22 July 23 July 25 ²²	1 1 1 1	1 1	 1 1
Total.....	32	.....	31	.....	29	.....	24	.....	19	.....	14	6	8

GROUP RECORD 47 (1919), INDOOR EXPERIMENT. HOST: LIME.

May 10.....	81	May 21 May 22 May 23 May 24 May 25 ²⁴	4 17 28 5 4	May 30 May 31 June 1 June 2 ²³ June 3 ²³ June 4 June 5 ²⁵	5 6 5 6 12 5 5	June 5 June 6 June 7 June 8 June 9 June 10 June 11 June 12 June 13 ²⁶	3 5 4 5 1 5 1 6 7	June 14 June 15 June 16 June 17 June 18 June 19 June 20 June 21 June 22 June 23 June 24 June 25 June 26 ²⁷	1 5 3 2 2 4 0 1 7 2 1 2 3	July 11 July 14 July 17 July 18 July 20 July 25 July 28 July 29 July 31 Aug. 1 Aug. 2 Aug. 4 Aug. 10 Aug. 15 Aug. 18 Aug. 20 Aug. 22 Sept. 3 Sept. 19 Sept. 25 Sept. 28 Sept. 30 ²⁸	1 1 3 1 1 1 1 1 1 2 2 2 1 1 1 2 1 2 2	1 1 2	 1 1 1 1 1 1 1 2 1 2 1 1 1 2 1 2 2
Total.....	81	.....	58	.....	45	.....	37	.....	33	.....	30	11	19

¹⁸ All eggs hatched; 1 first larval instar individual lost in settling down.¹⁹ Two first larval instar individuals died in that stage.²⁰ Five second larval instar individuals died in that stage.²¹ Five third larval instar individuals died in that stage.²² Trees sprayed with nicotine oleate on July 25 and 5 pupae, 3 females, and 2 males were killed.²³ Three second larval instar individuals removed for study. These had just molted.²⁴ Fifteen eggs failed to hatch. These were not parasitized. Eight first larval instar individuals were lost before settling down.²⁵ Three first larval instar individuals (still alive) removed for study. Ten first larval instar individuals died in this stage.²⁶ Two second larval instar individuals died in this stage.²⁷ Four third larval instar individuals died in this stage.²⁸ Three pupae still unreported on.

TABLE VI.—*Life history of Aleurocanthus voglumi*—Continued.

INDIVIDUAL RECORD 1 (1919), INDOORS. HOST: LIME.

Egg laid.	Num-ber.	Hatched.	Num-ber.	Indi-vidual num-ber.	First molt.	Time.	Second molt.	Time.	Third molt.	Time.	Sex.	Adult.	Time.
June 7.....	22	June 20, a. m. 1.	18	1	Died in molting, June 29.....	Days.	Fell off, July 4.....	Days.		Days.			Days.
				2	June 28, p. m.....	8	do.....						
				3	June 27, a. m.....	7	do.....						
				4	do.....	7	do.....						
				5	do.....	7	do.....						
				6	June 29, p. m.....	9	do.....						
				7	June 27, p. m.....	7½	do.....						
				8	June 27, a. m.....	7	do.....						
				9	June 27, a. m.....	7	Dead, July 7.....						
				10	June 27, a. m.....	7	Fell off, July 5.....						
				11	June 28, p. m.....	8½	Fell off, July 4.....			9½	(2)	Aug. 8, p. m.....	24
				12	June 27, a. m.....	7	do.....						
				13	June 27, p. m.....	7½	do.....						
				14	June 27, p. m.....	7½	do.....						
				15	June 27, a. m.....	7	July 7, p. m.....			9½	(2)	Aug. 20, p. m.....	34
				16	June 28, p. m.....	8½	Fell off, July 4.....						
				17	June 28, a. m.....	8	do.....						
				18	Fell off, June 26.....		do.....			9	(3)	Aug. 7, p. m.....	23½

INDIVIDUAL RECORD 2 (1919), INDOORS. HOST: LIME.

Egg laid.	Num-ber.	Hatched.	Num-ber.	Indi-vidual num-ber.	First molt.	Time.	Second molt.	Time.	Third molt.	Time.	Sex.	Adult.	Time.
June 7 ²	28	June 19..... June 20..... do..... June 19..... do..... June 20..... do..... June 19..... June 20..... do.....	(?) (?) (?) (?) (?) (?) (?) (?) (?) (?)	1 2 3 4 5 6 7 8 9 10 11 12	July 1, a. m..... June 27, p. m..... June 29, a. m..... do..... June 28, p. m..... June 30, p. m..... July 1, a. m..... June 29, a. m..... June 28, a. m..... Died..... July 4, a. m..... June 30, a. m.....	12 7 9 10 9 11 10 11 9 14 10	Died..... July 5, a. m..... July 6, p. m..... Died..... do..... July 7, p. m..... July 8, a. m..... July 9, p. m..... July 5, p. m..... July 15, a. m..... July 7, p. m.....	7½ 7½ 7½ 7½ 7 7 9½ 7½ 11 7½	July 16, p. m..... do..... do..... do..... July 16, p. m..... do..... July 27, p. m..... July 16, p. m..... Died..... July 16, p. m.....	11½ 10½ 9 18 11 9	(2) (4) (2) (4) (4) (4)	Aug. 23, a. m..... do..... Aug. 18..... Sept. 30, a. m..... Aug. 18..... Aug. 16, a. m.....	37½ 38 75½ 83 31

²Two first larval instar individuals fell off before settling down.⁴Male.¹One egg unhatched; three first larval instar individuals lost before settling down.²Female.

TABLE VI.—*Life history of Aleurocanthus woglumi*—Continued.

INDIVIDUAL RECORD 2 (1919), INDOORS. HOST: LIME—Continued.

Egg laid.	Num-ber.	Hatched.	Num-ber.	Indi-vidual num-ber.	First molt.	Time.	Second molt.	Time.	Third molt.	Time.	Sex.	Adult.	Time.
June 7.....	28	June 20.....		13 14 15 16 17 18 19 20 21 22 23 24 25 26	June 27, a. m. Died June 27, p. m. Gone, June 28 June 29, a. m. June 30, a. m. Died June 29, a. m. July 6, p. m. June 29, a. m. June 29, a. m. June 28, a. m. July 4, a. m. Gone, June 26	Days. 7 7 7 9 10 9 15 8 11	July 5, p. m. Died July 6, a. m. July 8, a. m. July 7, p. m. Died July 6, a. m. July 5, a. m. July 13, a. m.	Days. 8 8 8 8 8 7 7 11	July 14, a. m. July 14, a. m. July 17, p. m. July 16, p. m. July 15, a. m. July 14, a. m. July 30, a. m.	Days. 9 9 9 9 15	(4) (4) (4) (4) (4) (4) (4)	Sept. 27, a. m. Sept. 28, a. m. Sept. 28, a. m. Sept. 28, a. m. Aug. 11, p. m. Sept. 13, a. m.	Days. 74 ¹ 76 76 76 29 ¹ 46

INDIVIDUAL RECORD 3 (1919), OUT-OF-DOORS. HOST: LIME.

June 17.....	15	June 30.....	15	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	July 11..... Fell off, July 2 July 9, p. m. July 8, p. m. July 10, a. m. July 9, p. m. do. July 8, p. m. July 9, p. m. July 8, p. m. Fell off, July 9 do. do. Fell off, July 2 July 11, p. m.	11 9 8 10 9 9 8 8 8 8 8 8 11 15	July 18, a. m. July 17, p. m. Fell off, July 8 July 18, p. m. July 16, p. m. July 18, p. m. July 16, a. m. Fell off, July 9 do. July 16, a. m. do. do. July 18, p. m. Fell off, July 15	7 8 8 8 ¹ 7 8 7 ¹ 8 8 8 8 7	July 28, a. m. July 27, a. m. July 27, a. m. July 24, a. m. July 26, a. m. July 24, a. m. July 24, a. m. do. July 24, a. m. July 24, a. m. July 26, a. m. July 26, a. m.	10 9 ¹ 8 ¹ 7 ¹ 7 ¹ 8 8 8 8 10 8	(2) (2) (2) (4) (4) (4) (4) (4) (4) (4) (4) (4)	Aug. 19, p. m. Aug. 21, a. m. Aug. 20, a. m. Aug. 15, a. m. Aug. 24, a. m. Aug. 15, a. m. Aug. 16, a. m. Aug. 18, a. m. Aug. 16, a. m.	22 ¹ 25 24 22 29 22 23 23 23
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² Female.⁴ Male.

EGGS.

The eggs (Pl. VIII, A, B) are normally laid in spiral form, when the adults are undisturbed, but there is a great irregularity in the shape of these "masses." In fact it is doubtful if more than 50 per cent of the eggs are laid in this form. Egg laying has been observed as short a time as 18 hours after the emergence of the adults (young tree and petri dish experiments in the laboratory) and as long a time as four (or more) days in individuals of unknown previous history brought into the laboratory on young citrus shoots for observation.

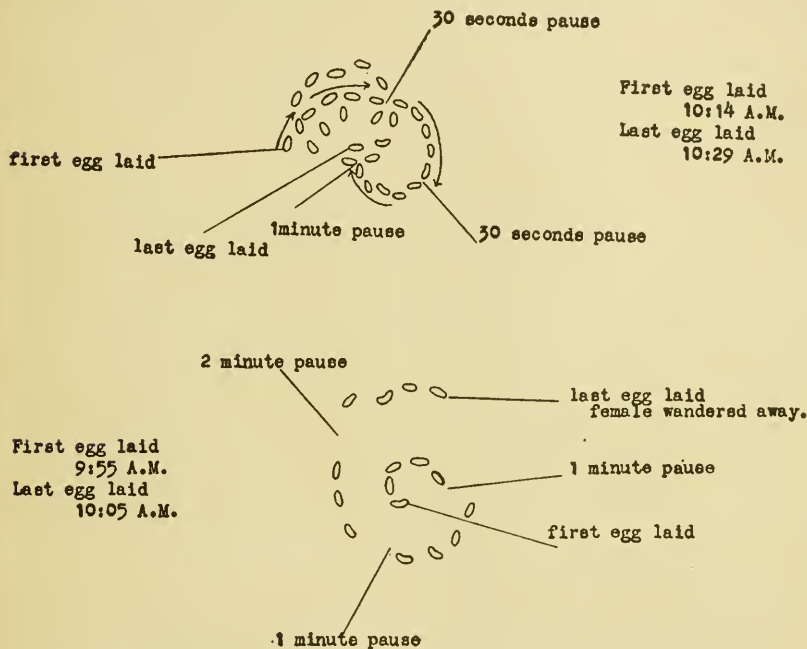


FIG. 6.—Diagrammatic drawings showing the procedure in oviposition of *Aleurocanthus woglumi*.

In laying eggs (fig. 6) the female usually starts at what becomes the center of the spiral (although the inverse of this has been observed) and facing outward begins a series of nervous vibrations and contractions. After from one to four such contractions and a rocking backward and forward she suddenly thrusts the end of her abdomen against the leaf and lays an egg, there being a noticeable contraction of the abdomen as the egg is expelled. During this oviposition the costal margins of the forewings rest against the surface of the leaf and serve to steady the female. The entire time for the deposition of a single egg including the shaking movement is usually from 15 to 30 seconds but sometimes takes as long as one or two minutes. After laying an egg the female moves forward a little, one-half the length of her body or more, and repeats the operation. When she has laid from 3 to 5

eggs, there is a rest of from 30 seconds to several minutes before oviposition is resumed and the female sometimes wanders around with wings fluttering, especially when observed. Since the distance which the female moves forward is variable and since she may be disturbed by other individuals on the leaf or by obstacles such as pupa cases or scale insects, the egg mass is often far from being a spiral. The figures show two masses. Molino and Dietz have observed 15 and 17 eggs laid in 15 minutes and likewise have seen as few as 3 eggs laid in 10 minutes.

In the field it has been observed that on bright sunshiny days the eggs are laid in the morning before noon, or in the late afternoon, times at which the relative humidity is highest. On cloudy days, when the relative humidity is fairly constant, egg laying may take place at any time during the day.

Normally, the eggs are laid on the undersides of the leaves, the females being negatively phototropic at the time of oviposition as is shown by the fact that when leaves on which females are laying eggs are turned over oviposition invariably soon ceases. In many cases a female will lay eggs within a few millimeters of the pupa case from which she has emerged. Likewise females seem to show little judgment as to where they lay eggs, this often resulting in decided overcrowding of young growth with eggs and the subsequent death of large numbers of developing individuals. Attention has been called to this under the heading "Spread of the insect," page 12. On a young orange on September 9, 1918, 50 spirals were counted on a single leaf and the following numbers were counted: 500 eggs in an area 10 by 30 mm. and 800 eggs in an area 20 by 25 mm. On September 30 there were at least 3,500 eggs on each leaf.

Some writers have called attention to the fact that eggs are laid on the fruit, and Morrison succeeded in getting a female in captivity to lay a normal spiral on a lemon fruit. Numerous inspections of lime, orange, and tangerine fruits on well-infested trees have failed to show that oviposition on the fruit in the field is a normal thing, for no stages of the black fly except occasional adults have ever been found on such fruit. Out of ten attempts, using 750 mixed adults brought in on young growth where they had clustered and confining them on half-ripe lime fruits, only one spiral of 19 eggs was obtained whereas a number of freshly laid spirals were found even on wilted leaves. Hence, it may be assumed that only on certain occasions and under certain conditions will eggs be found on the fruit of infested trees. This will probably be when the fruit is well shaded and the tree very heavily infested.

The number of eggs in a spiral or "mass" is as subject to variation as is the shape of the "masses" themselves and varies from 7 to 81, these being the extremes. Out of 118 spirals consisting of 3,798 eggs

the average was 32.19 eggs per spiral. However, the number of eggs laid in the laboratory on young shoots brought in from the field on which the adults had gathered was 26 per spiral, as against 36 for eggs laid on the leaves out of doors under natural conditions. Furthermore, out of 50 spirals laid in the laboratory only 8 had above 30 eggs and only 3 above 40, whereas out of the same number of spirals laid in the field 28 had above 30 eggs and 20 above 40. Hence, the normal number of eggs per spiral is between 35 and 50. Since different females have been observed to lay eggs as soon as 18 hours after emergence from the pupa case and as long as 4 days after emergence, there is but one conclusion, namely, that more than one spiral or mass of eggs is laid and that a single female may lay considerably over 100 eggs in her lifetime. If this were not the case, in view of the high mortality, especially in the early stages of development, it is doubtful if *Aleurocanthus woglumi* would be a pest of even secondary importance.

The individual egg is canoe shaped with its ends rounded. It is attached to the leaf by a short pedicel situated near its posterior end. When first laid the eggs are creamy white with what appears to be a reticulation of the surface, but in 36 to 48 hours they become brown in color, the reticulate appearance disappears, and they become blackish between the eighth and tenth days. In from 11 to 20 days the eggs hatch, the larvæ crawling forth through a slit along the median dorsal surface of the egg, the brown eggshell remaining plump and often very confusing as the slit seems to close again. Drying out of the leaves on which the eggs are laid seems to kill them, until one or two days before they are ready to hatch, as is shown later.

FIRST LARVAL INSTAR.

The larva that emerges from the egg is rather elongate ovate in shape, whitish in color, with reddish eye spots, short antennæ, and rather short legs. It crawls around sluggishly for from two to four hours and then settles down, the farthest distance crawled, out of 580 individuals, being $1\frac{1}{2}$ inches from the center of the egg spiral. But fully 80 per cent of the larvæ never crawl more than one-half inch away from the spiral from which they emerge. On settling down the larva describes an arc of from 75 to 120 degrees, evidently to help in inserting its thread-like rostral setæ into the tissues of the leaf. This movement seldom lasts more than 20 minutes. Two hours after emergence from the egg the larvæ are dusky all over, with the exception of the margins, and within four hours they are fully colored, i. e., blackish, and more broadly ovate than on emergence. There is a tendency for them to flatten out. There is a pronounced median ridge, on each side of which, anteriorly and posteriorly, are four long dorsal spines and numerous shorter ones. Larvæ that have settled once have been observed to change their

position and go through the same rotating movement on settling down again. On leaves bearing large numbers of spirals or on small leaves, as in the case of orange jessamine (*Chalcas exotica*), the larvæ seem to show a tendency to settle down along the smaller veins of the leaf and parallel to them, but this position is lost, due to the rotation that takes place in the later larval instars just after molting.

The duration of the first larval instar ranges from 7 to 16 days, at which time the first molt takes place. In a great many cases, especially out of doors, larvæ that fail to molt before the sixteenth day fail to mature. The mortality in this instar, as is shown in both laboratory and field life-history work, is exceptionally high. Out of 580 individuals that entered this stage of development 190, or about 32 per cent, died.

SECOND LARVAL INSTAR.

As the insect molts from the first to the second larval instar (Pl. VIII, A), a whitened margin along the sides of the insect can be seen as much as two days before the actual molt takes place. The individual has a decidedly distended appearance, and there is a slight constriction (almost unnoticeable in the first molt) on the side of the body apparently at the junction of the thorax and abdomen. Just before molting there is also a decided bulging along the line of the thorax and abdomen forming a transverse ridge. The insect seems to burst the anterior latero-ventral margin of its skin by pushing forward, and flows forth much like a drop of cream-colored viscous liquid. It begins at once to flatten out, being more ovate in shape than in the previous instar and quite disklike. This flattening out causes the skin to tear farther and farther back until at last the insect is free, with the skin attached to the dorsal spines. At this time the insect, both to free itself from its cast skin and to insert its rostral setæ, goes through some rather violent movements. It begins to rotate, describing an arc of from 45 to 180 degrees, and at the end of this movement it may raise the posterior portion of the body until it is almost over the anterior portion, so that as viewed from the side the insect would have a crescentic appearance. The insect may stay in this position as long as 5 minutes. Then again the posterior end of the body may be raised only slightly, and this movement be alternated with a "cupping up" movement, the insect assuming the shape of a person's hand when it grasps a pen. Or again at the end of each rotation the insect may merely rest for from 30 to 70 seconds. The time for normal procedure seems to be: Time to cast skin, 7 to 10 minutes; rotation with miscellaneous movements, 15 to 30 minutes. The entire time of molting, therefore, is about 40 minutes for the first molt. Several times it has been observed that insects started to molt and did not complete the operation until 24 hours later.

The early second larval instar individual is whitish in color, more ovate than in the preceding instar, and more or less flattened, with the eye spots and vasiform orifice quite prominent. Within three to four hours after molting the second larval instar becomes fully colored, i. e., dull black with the exception of a large, more or less circular spot on the anterior part of the dorsum, which remains a dull green. The insect is also decidedly more convex than in the preceding instar and the spines are more numerous and more prominent. The cast skin usually, though not always, remains attached to the long dorsal spines and rests near the middle of the dorsum of the second larval instar individual.

The duration of this instar ranges from 5 to 30 days in laboratory individuals, though the maximum time that has been observed out of doors is 21 days. The large majority of individuals molt between the eighth and thirteenth days.

Just before the second molt a color change takes place, which is noticeable from 18 to 30 hours before the skin is shed. This may be due to the distention of the individual at this time. Instead of a circular greenish area on the anterior dorsum one finds a crescentic black area anteriorly and a horseshoe-shaped area posteriorly and the green area more or less cruciform. The margin of the insect is whitish, just as it is in the premolting period of the first larval instar.

In life-history studies conducted by the writers, out of 390 individuals that entered this stage, 84, or about 21.5 per cent, died.

THIRD LARVAL INSTAR.

The procedure in the second molt is the same as in the first, although the various stages in this process are more rapid and of shorter duration; the duration of the entire operation from the splitting of the skin to the complete cessation of the rotating and "cupping up" movements is from 15 to 20 minutes. The movements, though more easily observed than in the first molt, do not seem to be nearly as violent.

The time required for individuals to become fully colored, i. e., shiny black, is from one and one-half to two hours. The only portion of the body that does not become black is a more or less hemispherical dull green spot on the anterior part of the dorsum, situated over the greater part of the thorax and the anterior part of the abdomen. The spines are more numerous and stouter than in the second larval instar and the cast skin of the preceding stage (and often stages) remains attached to or entangled in the spines of the middle part of the dorsum. The convexity of the individuals becomes pronounced and the insect is distinctly ovate in outline.

In this instar (Pl. VIII, B) sexes can be distinguished with certainty for the first time in the developmental stages, the males being at least one-third smaller than the females. The only complication in distinguishing the sexes seems to be between males and undersized females, although the latter are somewhat larger than the former.

The duration of the third larval instar is from 6 to 20 days, although out of doors the majority of individuals molt a third time between the eighth and fourteenth days after the second molt.

No color change has been observed in the third larval instar individuals preceding the third molt except that the dorsal hemispherical

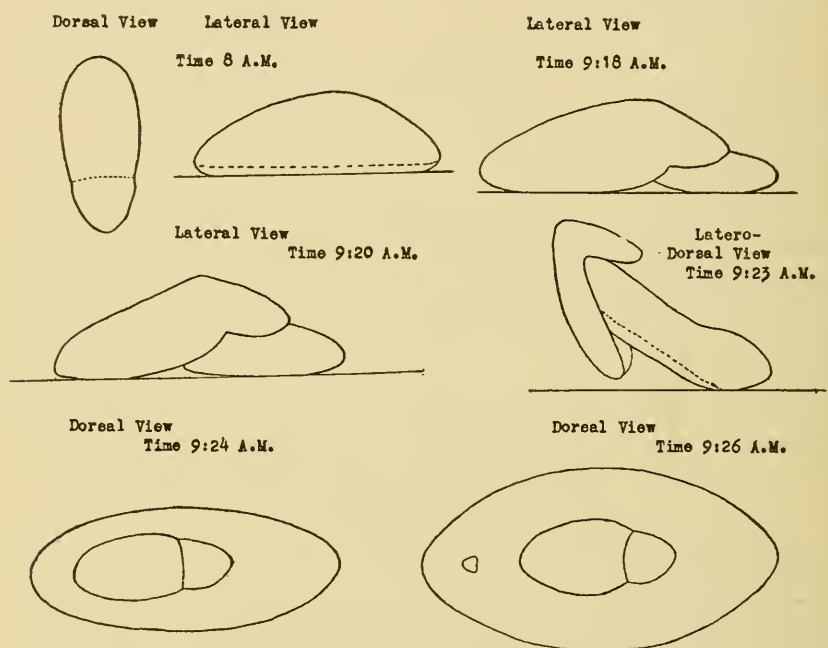


FIG. 7.—Diagrammatic drawings of the molting of *Aleurocanthus woglumi*: Third molt.

spot often becomes a lighter green and the whitish margin becomes very pronounced from one to four hours preceding the actual molting of the individual. Careful study of this has been made and appears to be due to the distention of the insect which permits the individual beneath to show through.

Of the individuals with which the writers worked, 38 out of 306, or almost 12.5 per cent, died.

FOURTH INSTAR OR PUPA.

The third molt takes place very rapidly, the entire process being completed in 15 minutes. (See fig. 7.) The individuals are pale cream-colored, flat, and the marginal teeth are not visible immediately

after molting, but are pushed forth within the first 10 minutes. The individuals are flat at first and at the end of 15 minutes they become distended, with the numerous spines standing out conspicuously. The time for complete coloration, i. e., until the shiny black color so characteristic of this stage is reached, is from one to one and one-half hours.

The shape is distinctly ovate in outline, the anterior being the smaller end. The insect is decidedly convex, with a prominent ridge, and is covered with numerous long, stout, conspicuous spines.

The sexes are readily distinguished, the female pupæ being almost twice the size of the males. Furthermore, a white wax is secreted around the margins of the body, the males usually secreting noticeably more than the females.

The duration of the pupal period is very irregular and ranges from 16 to 80 days. Out of doors the maximum time that has been recorded is 48 days.

The mortality in this stage is not as great as in the preceding stages, only 28 out of 268 individuals, or little more than 10 per cent, dying.

In all the larval instars and in the pupal as well, shortly after the molting, it has been repeatedly noted that drops of a clear, more or less viscous fluid appear at the ends of practically all the spines. No openings have been noted at the ends of these spines after the insects have become fully colored, and they may only function for a short time and close, though this would seem to be a rather unusual condition. In some of the members of the genus *Aleurocanthus* the spines are distinctly open and in the genus *Siphoninus* the ilquid has been seen actually flowing from these openings.

In the larval and pupal stages varying amounts of honeydew are excreted through the vasiform orifice, some colonies of individuals secreting more than others. The amount of honeydew excreted depends upon the rate at which the insects are feeding. The honeydew falls on the leaves below the infested ones and soon sooty molds, fungi of the genus *Meliola*, begin growing on it. The heavy growth of the sooty molds on upper surfaces of the leaves, coupled with an abundance of *A. woglumi* individuals in various stages of development on the under surfaces, doubtless seriously interferes with the normal functioning of the leaves. (See Pls. V and VI.) Further, this double infestation may be so severe as to render leaves practically worthless to a tree and thus seriously interfere with its vigor. But infestations of *A. woglumi* are not necessarily accompanied by heavy growths of sooty mold, and the writers have found trees practically free from this insect and yet covered with heavy growths of these molds. In such instances the trees were usually badly infested with

nondiaspine scale insects or plant-lice which seem to excrete far more honeydew than does the black fly.

FIFTH INSTAR, ADULT OR IMAGO.

When the adult (Pl. IX) is ready to emerge from the pupa case a T-shaped split appears at its anterior portion, the stem of which arises at the middle of the anterior margin and extends caudad along the median dorsal line to the junction of the thorax and abdomen. The arms of this T-shaped split extend to the right and left along the suture separating the thorax and abdomen. This split is visible from one-half hour to an hour before the adult begins to push forth. In emerging the adults push against this split, causing it to spread wider and wider open, and by a wriggling and up-and-down movement, interspersed with numerous rests to allow for some hardening of the various parts of the body, they finally succeed in escaping. Often they fall out in spite of desperate efforts to cling to the leaf and drop to the ground, where many probably die or fall victims to such insects as the ants. The time taken for normal emergence is from 14 minutes to one-half hour, though under dry conditions it may be as long as an hour and a half, or the insect may die without being able to escape.

The adults after freeing themselves from the pupa case usually rest beside it until various parts of their body become hardened, the only movements being more or less nervous ones, such as twitchings of the legs or wings to speed this process along.

When the adults first emerge the greater part of the body, i. e., the head, thorax, and abdomen, are a bright brick-red in color, with the front of the head (the vertex) pale yellow, the antennæ and legs whitish, and the eyes a deep red or reddish brown. The wings begin to fill out and are full size in from 18 to 30 minutes after the insect has emerged. In cases where the adults have trouble in freeing themselves from their pupa cases, the wings begin filling out, nevertheless, and thus may become crippled. After about one hour, the head, thorax, wings (with the exception of the colorless or whitish areas), and legs are quite dusky, but the sutures on the thorax and the entire abdomen remain a brick-red in color and the antennæ more or less whitish tinged with pale yellow. The eyes become a deep reddish brown. Within 6 to 12 hours the adults are fully colored, the color being merely an intensification of that previously set forth, the sutures of the thorax becoming smoky.

Within 24 hours after emergence, the insects become covered with a heavy pulverulence so that they have a general slaty blue appearance, with the colorless spots on the wings, when these are at rest, forming what appears to be a white band across the middle of the dorsum.



THE BLACK FLY.

Adults clustered on a young lime shoot. Natural size.

In the field the males are readily distinguished from the females by their noticeably smaller size and on closer observation by the difference in the structure of the end of the abdomen (see "Technical description," p. 41).

Humidity seems to be a very important factor in the time that emergence of adults from the pupa cases takes place, the maximum emergence in the field occurring in the early morning between 6 and 9 o'clock and dwindling down toward noon. Considerable emergence may take place in the late afternoon, following a rain, or at any time on cloudy, humid days.

After the bodies of the adults become hardened, the adults may rest by the pupa cases for anywhere from 3 hours to 5½ days in laboratory experiments. In the field the longest time observed was 1 day. Females often lay eggs within an inch or less of the pupa cases from which they have emerged, especially on lightly infested leaves. When they have left their original position, after the hardening of the body, it seems to be an instinct of both sexes to congregate on the young growth of an infested tree probably both to obtain food and to insure fertilization of the females. Since it has been observed that females will lay eggs within a short distance from the pupa cases from which they have emerged it is probable that in the miscellaneous gatherings of adults on the young shoots three kinds of females are present: Those that have laid no eggs; those that have laid part of their eggs; and those that have laid all of their eggs.

Numerous counts of the number of males and females on the young growth of heavily and moderately infested trees were made in order to determine the ratio of the sexes present. On the heavily infested trees the number of males and females was usually equal. At times, however, the females would outnumber the males as much as 8 to 3. On the moderately infested trees there was a wide difference in the ratio of the sexes present, the proportions ranging from 5 males to 1 female to 7 females to 1 male. For the most part the females were more abundant. In counts made of the ratio of the sexes present in the pupal stage out of 25 colonies selected at random from moderately infested trees, 230 were females and 159 were males. On miscellaneous orange leaves, heavily infested, 450 were females and 471 were males. Out of 20 life-history spirals, 91 pupæ were males and 152 were females. This would tend to show that the females were more numerous than the males, and that the wide range in the numbers of each sex present at different times is probably due to the variation in the duration of the pupal stage even in the same colony.

Mating has been observed both in the field and in the laboratory. In the field it may take place at any time of the day, but seems to be more frequent in the late afternoon than at other times, due to the constantly increasing number of adults that gather on the young

growth throughout the day. The following is the procedure as observed in the laboratory on July 12, 1919: At 2.30 p. m. a number of young shoots on which a large number of adult males and females had gathered were brought in. The females were in the majority, there being about 5 females to every 2 males. These were carefully observed from 2.30 until 5 p. m. and copulation between at least 20 males and females (40 individuals) was witnessed. The males were found to rest beside the females with their bodies parallel to those of the females. Occasionally two males were found one on either side of a female. At intervals a certain nervous fluttering of the wings of the males was seen. This was carefully watched.

Beginning with a male resting beside a female, both acting normally, the following observation was made: The males would rest quietly beside the females for from three to five minutes. Then they would begin fluttering their forewings slowly and rhythmically at first. This fluttering of the wings continued with increasing intensity until it was very violent and consisted of very short rapid jerks, the forewings extending forward over the thorax and head of the insect at an angle of 120 degrees. Sometimes they stood straight up at an angle of 90 degrees to the body. The hindwings sometimes, though not always, were held rather close to the body and never more than an angle of 15 degrees away from it. In the height of this very rapid wing vibration there was a sudden pause with the wings extended forward. Then with an exceedingly rapid and sudden jerk the male thrust his abdomen under the normally resting wings of the female and the connection was made, apparently by the female being ready to receive the male and by moving the end of her abdomen into the proper position simultaneously with the male. The trembling movement lasted from 25 to 45 seconds and the mating lasted from 40 to 50 seconds. During the time that the male was going through his preliminary movements, the female was passive, except that she would occasionally and irregularly give her wings a sharp sudden jerk, and move her legs, especially those on the side by the male. This movement was very inconstant.

Two males were observed trying to mate with the same female, though only one was successful, in contrast to what has been observed in *Calopteron juvenile* Gorh., a lampyrid beetle, where five males have been found mating with the same female. A male has also been observed to mate with the same female three times in 20 minutes, and another male was seen to mate with three comparatively widely separated females in the course of half an hour.

Mating has been observed between individuals whose coloration would indicate that they were not more than 12 hours old. It has also been observed that if a female would move during the preliminary stages of the mating the male would wander about aimlessly in search

of her. Attempts to induce mating between individuals of known history were all unsuccessful, due to the nervousness of these individuals when confined.

When confined the adults seem to be positively phototropic and always gather at the side of the cages where the light is brightest. It is perhaps this reaction to light that guides them to the young growth of the tree, but once they reach this growth they invariably gather on the undersides of the leaves and avoid light, for if a shoot on which adults have gathered is turned so that the undersides of the leaves are exposed to strong light the adults immediately become nervous and wander around to the opposite side of such leaves.

The length of life of adults is extremely hard to determine. Kept in glass vials with and without moisture some individuals of unknown previous history have remained alive as long as three days, though the large majority died within the first 36 hours. When allowed to emerge from pupæ on leaves kept in petri dishes individuals have lived as long as four days. Out of large numbers of males and females (approximately 800) on young shoots, brought into the laboratory from the field and placed in water, a few individuals have remained present as long as five days before taking to flight, and on emerging from pupa cases in life-history spirals in the laboratory several females have remained within a few millimeters of the pupa case from which they emerged as long as six days and as short a time as two hours before flying away. Hence, it may be assumed that the life of the adults is at least a week and that it may be as long as 12 days, i. e., by adding the maximum time that they have remained near the pupa case and the maximum time that they have remained on the young shoots.

TECHNICAL DESCRIPTION.

The following technical description based on material from the Canal Zone has been prepared by Dr. A. C. Baker and Miss Margaret L. Moles, of the Bureau of Entomology.

EGG.

Plate XI, A.

Size 0.208 mm. by 0.08 mm.; shape elliptical, curved, with the stalk short and attached some distance from the base. Color yellowish, surface apparently without reticulations in some cases and with them in others, due, no doubt, to the structure being destroyed in boiling. When present they average 0.006 mm. in diameter.

FIRST LARVAL INSTAR.

Plate X, A.

Size averaging 0.304 mm. by 0.192 mm.; shape elliptical, broadest just cephalad of the middle pair of spines. Margin very minutely serrate; abdominal segments distinct but narrow; vasiform orifice oval, almost entirely filled by the operculum. Caudal margin with two pairs of prominent spines, the outer pair measuring 0.032

mm. and the inner pair 0.048 mm. Spines at the vasiform orifice rather short and thick, scarcely 0.032 mm. long. Thorax with a pair of stout, curved spines 0.020 mm. long, arising close to the median line just cephalad of the first abdominal segment. A second pair of spines 0.24 mm. long arising from the cephalic portion of the case near the median line. These are curved evenly backward. While minute teeth are present on the caudal margin, there is no indication of a caudal comb.

Color rather dark brown under the microscope, almost black on the leaf.

SECOND LARVAL INSTAR.

Plate X, B.

Size averaging 0.4 by 0.288 mm. Shape rather broadly elliptical, broadest across the caudal portion of the thorax. Margin minutely crenulate, caudal comb slightly differentiated. Abdominal segments not very distinctly separated. Vasiform orifice oval, slightly tending to triangular on caudal portion, operculum almost completely filling orifice. Inner pair of caudal spines hair-like, 0.096 mm. long, outer pair minute, spines at vasiform orifice about two-thirds the length of caudal pair. Dorsum with a number of stout, heavily chitinized spines situated as follows: A pair situated near vasiform orifice, each spine about 0.112 mm. long; two pairs somewhat cephalad of these and about equal in length, each spine about 0.144 mm. long; one pair near median line, each spine about 0.064 mm. long; and a pair just cephalad close to medial line, each spine fully 0.192 mm. long. Near the outer margin, slightly more cephalad, is a pair of spines 0.128 mm. long; close to the median line is a pair 0.192 mm. long, and cephalad of this two pairs, the spines about equal in length and measuring about 0.096 mm. Dorsum slightly arched but not prominently so. Color dark brown. The color changes of this and other instars have been treated elsewhere in this bulletin (p. 31 to 36).

THIRD LARVAL INSTAR.

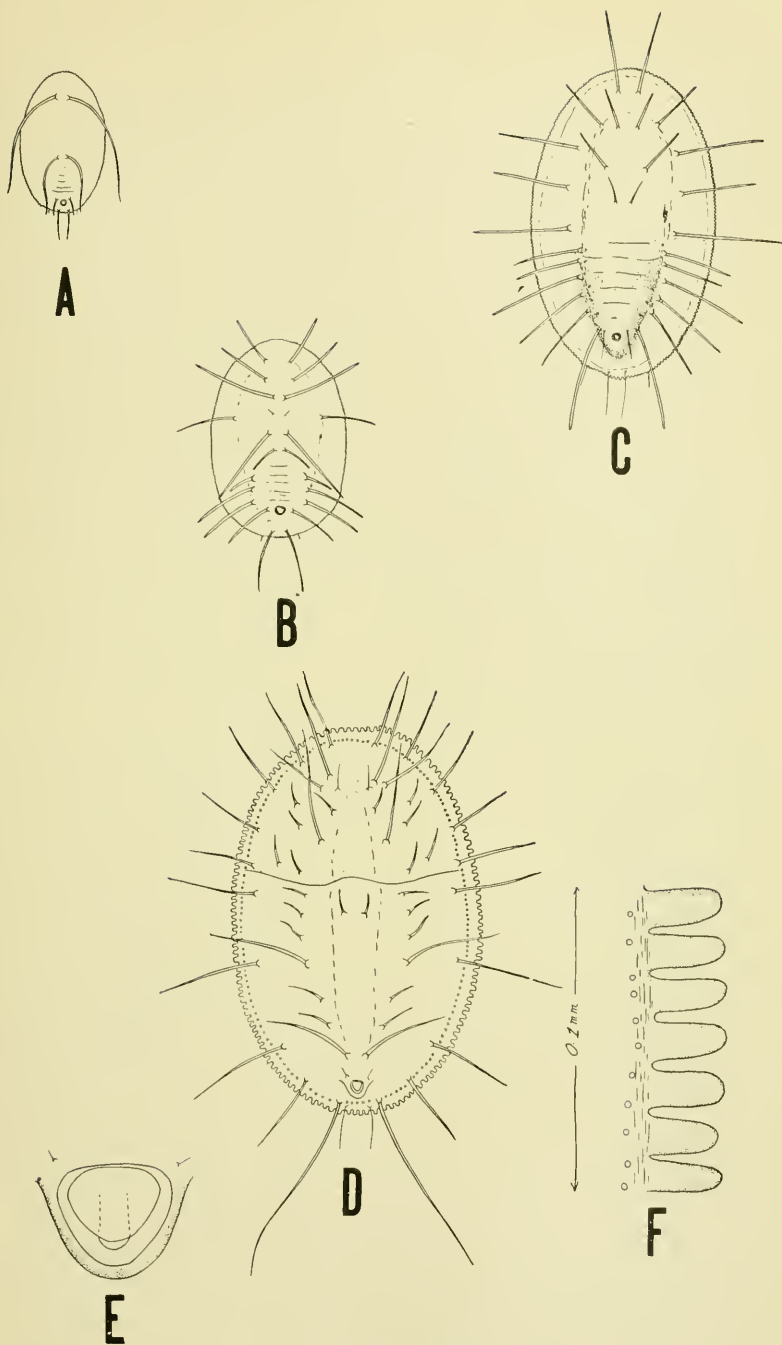
Plate X, C.

Size averaging 0.736 by 0.464 mm.; shape elliptical, broadest just cephalad of middle pair of spines. Margin crenulate; teeth 0.01 mm. in length, 0.007 mm. in width, caudal comb consisting of four marginal teeth slightly larger than the rest. Abdominal segments indistinct, a row of small, closed pores marking terminations of abdominal sutures. Vasiform orifice small, oval, situated on a slight tubercle, operculum cordate, filling three-fourths of the orifice. Lingula not visible. Dorsum with a number of stout spines of varying lengths situated as follows: A pair laterad and cephalad of vasiform orifice, each spine about 0.19 mm. in length; a pair of spines at termination of each abdominal suture, those on segments three and four being the longest. Seven pairs of spines on thoracic portion of dorsum, two short pairs near meson, a longer pair near cephalic margin of case, and four pairs outlining boundaries of thoracic segments of pupa case, the pair nearest to eye spots being 0.24 mm. in length, the pair at dorsal portion of thorax 0.30 mm. in length, the other two short and stout. A pair of long, slender setae situated cephalad and caudad of the vasiform orifice, and a short, stout pair on the metathorax near the meson. Dorsum slightly arched. Color dark brown.

FOURTH LARVAL INSTAR OR PUPA.

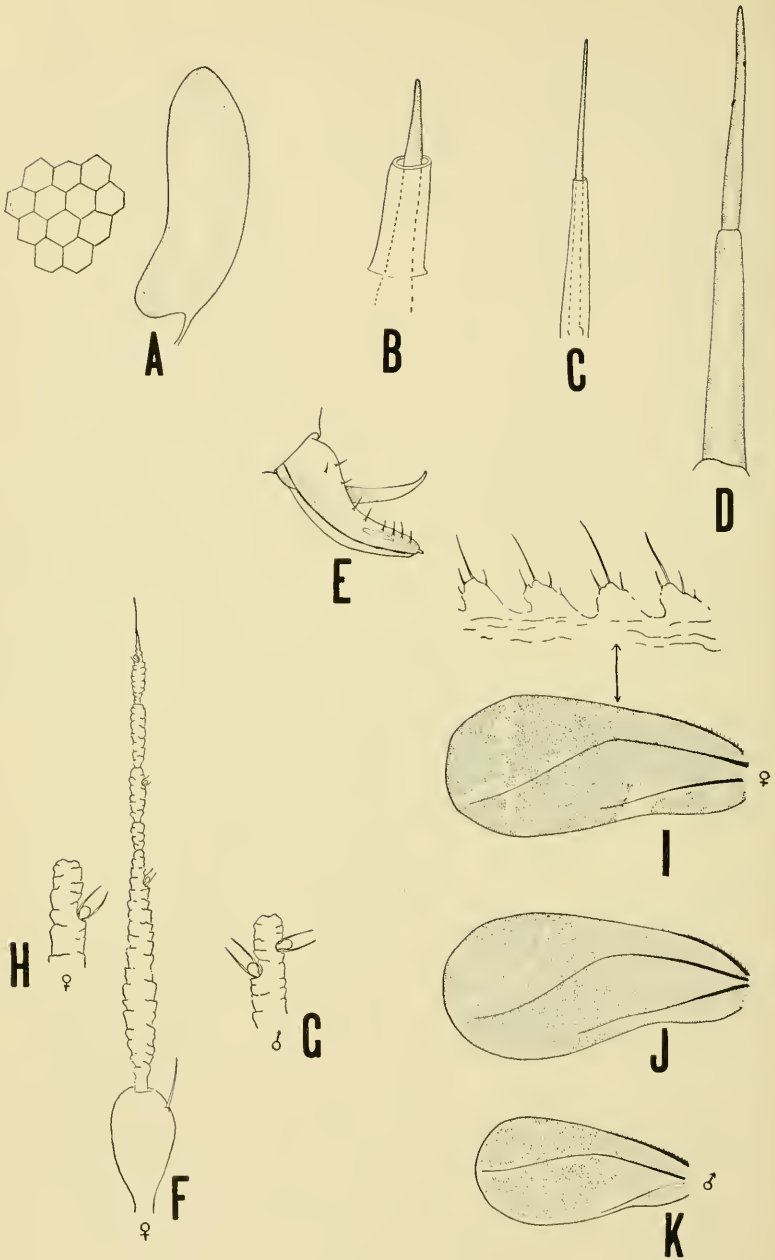
Plate X, D.

Size variable, averaging 1.5 mm. to 0.89 mm.; shape regularly elliptical with dorsum arched; median ridge high, but not markedly distinct from dorsal area, excepting near the caudal portion of abdomen and at vasiform orifice, which is elevated into a more or less prominent tubercle. Color dense black, so much so that even prolonged boiling in potassium hydroxid does not remove the color. When the denser dorsal



THE BLACK FLY.

A, Larva, first instar; B, larva, second instar; C, larva, third instar; D, pupa case; E, vasiform orifice of pupa case; F, margin of pupa case.



THE BLACK FLY.

A, Egg, with enlarged view of polygonal markings of egg; *B*, pupal spine immediately after molting; *C*, same, showing variation in outer sheath; *D*, pupal spine just before changing color; *E*, male genitalia; *F*, antenna of female; *G*, distal portion of segment III in the male antenna; *H*, distal portion of segment III in the female antenna; *I*, forewing of adult female showing costal margin at base of wing; *J*, same, showing variations in markings; *K*, forewing of male.

portion of the case is removed the ventral part appears under the microscope as dark brown and more or less irregularly mottled. Submarginal area with usually 20 spines forming a ring, varying considerably in length, but caudal pair nearly always longest. Spines curved outward. A pair of hairs present on caudal margin caudad of vasiiform orifice. Spines on dorsum small excepting two pairs on abdomen and three pairs on thorax. (Number and arrangement shown in Pl. X, D.) Vasiiform orifice prominent, being on a tubercle, but small and somewhat triangular in shape, tending to circular (Pl. XI, E). Operculum almost entirely fills orifice, obscuring lingula except for a very small portion at tip. Cephalad of orifice a pair of minute setae is situated, one set on each side. Margin of case dentate, teeth large and bluntly rounded (Pl. XI, F). A space of 0.1 mm. is occupied by six or seven teeth. On this feature alone the case is easily separable from those of the other species. At base of teeth, forming a ring around the case, is a series of minute, clear, porelike areas. On the leaf the case is jet black with the dorsum somewhat arched and the abdominal segments marked, but not distinctly separated. On the margin all around is a narrow cottony lateral wax fringe. This sometimes extends mesad, irregularly covering the submarginal area, but dorsal secretion is usually absent.

ADULT FEMALE.

Length from vertex to tip of ovipositor 1.12 mm.; color brown, under the microscope a deep wine color with darker shadings on head, thorax, and tip of abdomen. Vertex rounded and possessed of a slight median ridge. Eyes very dark brown. Antennae (Pl. XI, F) 0.311 mm. in length, segment III 0.117 mm. long, segment IV 0.018 mm., segment V 0.033 mm., segment VI 0.041 mm., segment VII 0.0367 mm. Segments III, V, and VII with a sensorium near the distal extremity of the segment (Pl. XI, H). Labium yellowish, tipped with black. Legs yellowish, shaded on femora with dusky. Femora and tibiae of the hind legs considerably darker than the others; length of hind femora 0.288 mm.; hind tibiae 0.432 mm. Tarsi having proximal segment 0.1 mm. and the distal 0.06 mm. Proximal segment armed on its distal extremity with one large spine and several smaller ones; foot normal, with paronychium straight and hairy. Forewings 1.268 mm. long and 0.76 mm. wide at the widest part. Radial sector heavy, yellowish brown in color, and much curved. Cubitus very fine, long and slightly curved, that portion of the wing below it forming a more or less distinct lobe. Wings (Pl. XI, I, J) a deep smoky color, except as follows: A line following the cubitus and a rather large spot near its distal extremity are colorless. A line following radial sector from its distal extremity to almost its median curve and another crossing it almost at right angles are colorless, giving the appearance of a white cross on a dark background. Marking in some wings not so evident, but there is one curved colorless line angling across the wing a short distance above and parallel with the radial sector. Border of this white line more heavily shaded than remainder of wing. Margin of wing armed with a series of rather prominent teeth directed toward the distal extremity of wing. Each one of these armed with one prominent spine and usually three smaller ones (Pl. XI, I, J). The margin formed by these teeth and a line along their bases is bright wine red. Hind wing uniformly smoky, with the vein yellowish brown.

ADULT MALE.

Much smaller than female, measuring only about 0.79 mm. from vertex to tip of claspers. Antennae 0.261 mm. in length, segment III 0.117 mm., segment IV 0.015 mm., segment V 0.026 mm., segment VI 0.031 mm., segment VII 0.023 mm. Segment III having two small sensoria near its distal extremity (Pl. XI, G), segments V and VII having only one. Color yellowish or reddish brown. Hind femora 0.24 mm. and hind tibia 0.4 mm. in length. Marked as in female. Claspers 0.126 mm. long. Near their distal ends there are a number of jagged teeth and they are armed

with a number of long, slightly curved hairs, those near the tip being the longest. Penis as long as claspers, yellowish, and almost straight. (Pl. XI, E.) (Forewing, Pl. XI, K.)

Described from females, males, and pupa cases in balsam mounts and pupa cases and eggs on the leaves.

It might not be out of place to discuss here the appearance of the spines during the period immediately after molting. As indicated on p. 35 there are seen on the spines shortly after molting drops of some material, apparently secreted by the spines, which is not seen after the spines have become fully developed and hardened. While we have available no fixed material and are, therefore, unable to make a study of the development of these spines, some information is obtainable from the material in hand which may throw light on the origin of this secretion.

Immediately after the molt the spines may be seen to consist of a distinct outer collar or sheath of about the thickness of the base of the fully formed spine and a central acute portion much narrower in diameter protruding from it. This can be traced through the center of the sheath and some distance beyond its base (Pl. XI, B). In others this outer sheath is more extended, as is also the central core. Here we are unable in the available material to trace the central core beyond the base of the sheath, although it is distinctly traceable within the sheath. (Pl. XI, C.) In somewhat later specimens the spines have reached their full length and we are unable to trace the core through the center of the sheath. Moreover, the portion of the core which extends beyond the sheath is much greater in diameter than in the specimens just discussed, although the line of demarcation is visible (Pl. XI, D). In somewhat later specimens in which the spines have begun to change color we are unable to locate any trace of this former division.

SEASONAL HISTORY.

From a study of the life-history charts it is evident that the life history is not clear-cut and that under conditions that obtain in the laboratory there is a constant lagging behind in some individuals which becomes most pronounced in the pupal stage. On the basis of the maximum and minimum times for the completion of the life cycle from egg to adult there is the possibility of from three to six generations per year with all sorts of overlapping of generations even from the same colony of individuals. Thus a seasonal history of *Aleurocanthus woglumi* would resemble somewhat that of the asexual generations of some of the plant-lice.

But another factor comes into play and that is the wide difference in the rainfall of wet and dry seasons in the Canal Zone as Table VII shows. This table is for the period during which the work given in this report was done. It is for the Pacific section and is based on

the monthly meteorological reports of the section of Meteorology and Hydrography of the Panama Canal, the observations being made at Balboa Heights.

TABLE VII.—Weather report for June, 1918, to May, 1919, inclusive, at Balboa Heights.

Temperature.			Wind.			Mean relative humid- ity.	Rain.			Month.
Maxi- mum.	Mini- mum.	Mean.	Pre- vail- ing direc- tion.	Hourly average move- ment.	Maximum velocity and direction.	Per cent.	Rainy days.	Maxi- mum in one day.	Total for month.	
° F.	° F.	° F.		Miles.	Miles per hr.			Inches.	Inches.	1918.
91	72	80.2	N.	6.6	23 N.....	88.4	17	1.58	5.20	June.
91	73	81.6	NW.	7.6	28 NW.....	88.6	13	1.75	5.13	July.
91	72	80.8	NW.	7.7	36 NW.....	89.0	14	1.07	3.84	August.
91	72	80.8	NW.	5.6	27 NW.....	89.6	13	2.35	7.03	September.
91	71	79.8	NW.	7.2	28 NW.....	89.8	19	2.20	9.16	October.
92	70	80.2	NW.	6.3	28 NW.....	90.1	16	2.46	9.61	November.
91	71	81.0	N.	9.4	28 NW.....	85.6	5	.24	.55	December.
1919.										
90	70	79.8	N.	11.5	32 NW.....	77.8	7	.12	.28	January.
94	70	81.4	N.	11.7	32 NW.....	74.4	0	Trace.	Trace.	February.
92	67	80.8	N.	13.7	36 NW.....	72.9	0	Trace.	Trace.	March.
93	72	81.6	NW.	9.1	31 NW.....	80.1	15	1.42	6.43	April.
92	73	81.2	NW.	6.5	30 S.....	86.0	23	1.29	5.21	May.

With such a radical change in the rainfall it is no wonder that the development of *woglumi* is decidedly checked. Attention has already been called to this under the heading of "Injury," page 18. Out of 12 spirals consisting of 421 eggs on trees exposed to a free play of the wind and started between December 8, 1918, and March 4, 1919, and observed by Mr. Molino, only 245 hatched, 52 reached the first larval instar, 15 the second larval instar, 14 the pupal stage, and 9 the adult stage. Hence, it is no wonder that an incipient infestation observed in Las Sabanas in January, 1919, died out by April of that year.

Furthermore, the citrus trees when not watered during the dry season make little or no growth, and such growth as was uninfested before the beginning of the dry season in places exposed to the wind remained so even on trees that were watered. Such young growth as was made on watered trees also remained practically free.

Likewise the abundance of adults during the dry season is an indication of the seasonal history. During the rainy season there usually is a considerable number of adults present on the young or on the terminal growth of an infested tree. At the beginning of the dry season in December, this abundance of adults shows a decided falling off, few or no adults being present on the terminal growth except for from four to five days following a shower. After a shower considerable numbers would be present, but they would dwindle down to none within three to four days. This was shown on three different

lots of trees under observation. Also during the exceedingly dry months of February (except on Feb. 15 and 16 following a shower on the 11th), March, and the first 14 days of April, practically no adults were found on the trees. But following the first heavy rain of 1.21 inches on April 13, 1919, the adults began to appear on the terminal and subsequent young growth in unusual abundance and continued in such numbers until the end of August. From the foregoing data it seems that what takes place in the laboratory in the life history also takes place out of doors in the dry season, and that at least one generation is lost during that season, making the maximum number of generations that occur in the Canal Zone, at least on the Pacific side, five instead of six.

PARTHENOGENESIS.

Parthenogenesis occurs in *Aleurocanthus woglumi* just as in other Aleurodidæ whose life history has been studied. Adults from two spirals obtained in the laboratory from unfertilized females have all been males, and in the field, especially at the end of the dry season, a considerable number of colonies were found, all of whose individuals were males. One of these colonies contained 72 male pupæ and another contained 44. Plate VIII, C, shows a colony of 32 male pupæ on a lime leaf. The reason that parthenogenesis occurs more frequently during the dry season is that many adults rarely emerge at any one time, so that those females that emerge during the months of January to April do not have as many chances for fertilization as those that emerge during the rainy season. As has been shown, the chief guiding factor of the males in finding the females and mating is the tendency or habit of large numbers of the sexes to congregate on the young or terminal growth of the trees.

NATURAL FACTORS THAT TEND TO CONTROL THE BLACK FLY IN THE CANAL ZONE.

There are two natural factors that tend to control the black fly in the Canal Zone and adjoining parts of the Republic of Panama. One is the drying out or lack of rains coupled with increased evaporation due to an increased average monthly wind movement during the dry season. This has already been referred to under "Seasonal history," page 42.

The other factor is the heavy rains that occur during the rainy season. Just after the molting periods and immediately after the emergence of the adults from the pupa cases, the black fly is in a very weak condition and heavy rains coming as they do at a decided angle doubtless wash off large numbers of them. That this actually does take place has been repeatedly observed in all the stages in the life-history work conducted by the authors in the field.

NATURAL ENEMIES.

So far no internal parasites of the black fly have been found in the Canal Zone or the Republic of Panama, although careful search was made for them.

Several predators on the insect have been found, most of which are coccinellids. These are *Hyperaspis calderana* Gorh. and *H. albicollis* Gorh.; *Scymnus thoracicus* For., *S. horni* Gorh., *S. coloratus* Gorh., and *S. adspersulus* Gorh.; and *Cryptognatha flaviceps* Crotch. Of these the last-named species is apparently the most abundant, but none of the coccinellid predators seems to occur in sufficient numbers to be of any value in controlling the insect.

The larvæ of a lacewing fly (*Chrysopa* sp.) have occasionally been taken feeding on all stages of the black fly. Judging from the number of empty skins of their victims (Pl. IV, fig. 2) that the larvæ carry around with them in the "basket" formed by the long upturned hairs on the margin of the dorsum, these predators, if they occurred in sufficient numbers, would exercise a considerable influence in the control of this pest. These chrysopids are in turn preyed upon by a hymenopterous parasite, specimens of which have been reared from their pupæ.

Several entomophagous fungi have been found to attack the larval and pupal instars of *Aleurocanthus woglumi*. These are *Aschersonia* spp. and *Aegerita webberi* Fawcett. These were taken on heavily infested trees in the Las Sabanas region in November, but were not abundant or well scattered enough so that any faith could be placed in their efficacy as a means of natural control for the insect. Examination, the following April, showed that the fungi had suffered severely during the dry season.

ARTIFICIAL CONTROL.

Since natural enemies are no factor in the control of *Aleurocanthus woglumi*, artificial control measures, such as spraying with insecticides, must be used. The successful control of this pest by sprays has already been mentioned by Ritchie (33) who used a modified "Florida citrus spray."

Sufficient work on the control of the black fly on a large scale has not yet been done in the Canal Zone to warrant any definite conclusions, but the preliminary control work that has been carried on refutes the idea that such radical measures as were of necessity used in the eradication of citrus canker are necessary to hold this insect in check.

The logical time to spray in the Canal Zone and adjoining parts of the Republic of Panama is in the dry season, as is shown by the meteorological data given under "Seasonal history," page 42. Data on sprays at this time have not been obtained.

Preliminary spray work, however, has been done during the rainy season with 5 and 10 per cent kerosene emulsion, fish-oil soap at the rate of 1 pound to 2 and 4 gallons of water, and nicotine oleate at the rate of 1 part of nicotine to 500 parts of water.

The kerosene emulsion stock solution was prepared according to the following formula: Kerosene, 1 gallon, laundry soap, 10 ounces, and water, 1 gallon. When agitated in an ice-cream freezer or similar device this formula makes an excellent emulsion and has the advantage that it can be readily diluted to any percentage without the use of complicated mathematical formulas. Thus to obtain a 5 per cent solution it is diluted with 18 parts of water since it already contains 1 part of the 19 necessary to make a total of 20.

Both the 5 and 10 per cent emulsions were effective controls though the 10 per cent emulsions caused some burning and were therefore discontinued. The 5 per cent emulsions proved very effective, and trees were completely freed from *A. woglumi* by one or two sprays. If two sprays were used they were given at intervals of one week.

The preliminary tests of fish-oil soap sprays were a decided surprise in that two sprays either at the rate of 1 pound to 2 gallons or to 4 gallons of water at intervals of one week completely freed trees not only of *A. woglumi*, but also of such scale insects as *Pseudaonidia* (*Selenaspidus*) *articulatus* Morg., *Chrysomphalus aonidum* Linn., and *Pseudococcus* sp. without causing injury.

The nicotine oleate was prepared according to the formula given by Moore (20). In the case of this spray it was necessary to apply it three times at intervals of a week before the trees were freed from all stages of the black fly.

Since all this work was done in the rainy season the efficacy of a spray was determined in two ways, (1) by counts made on large numbers of individuals in various stages of development and determining the numbers that were dead and alive, and (2) by the numbers of individuals that would "slough" or wash off during the heavy rains. It was found that when a spray was really effective practically all the dead black flies as well as the scale insects would be washed off during the heavy tropical rains, whereas on check trees or on those where the spray was a failure this did not take place.

The formulas recommended by W. W. Yothers for the control of the citrus white fly (*Dialeurodes citri* Ashmead) have not yet been tried owing to absence of suitable cheap oils of the type he recommends. However, in view of the success that has so far been obtained with both the kerosene emulsions and fish-oil soap sprays, the sprays recommended by Mr. Yothers should prove even more effective due to the fact that their "high boiling point and great viscosity make them operative over a longer period of time after application, and, too, they are only slowly affected by average temperature and showers."

POSSIBILITY OF THE INSECT BEING INTRODUCED INTO THE UNITED STATES AND FACTORS INFLUENCING ITS ESTABLISHMENT HERE.

The presence of the black fly in Cuba, in the region of Habana, and on the island of New Providence is doubtless a menace from the point of view of the possibility of its introduction into Florida and becoming established there. Theoretically there are several ways that such introduction may take place. The first of these methods is on nursery stock infested with any or all stages; the second is on infested individual plants or parts of plants infested with eggs or pupæ brought in by travelers from Cuba or Nassau; the third, by eggs of the insect laid on fruits; the fourth, by infested parts of plants mixed in shipments of fruits; and the fifth, by adults brought in on freight cars from Cuba via the railroad ferry plying between Habana and Key West. In the case of insects like the Aleurodidæ the stages that are introduced and the conditions under which they are introduced and to which they are subjected after introduction have a decided bearing on whether or not they will be able to maintain themselves and become established.

The first and second of these methods are the ones by which the insect is most likely to gain entrance into the United States and become established here, for the high mortality that takes place, especially in the early stages, means that plants or parts thereof brought into a new locality must be well infested if the insect is to establish itself. This is the way the insect became introduced into Jamaica, Cuba, the Canal Zone and Panama, Costa Rica, and New Providence.

Heavily infested parts of plants will have to be brought in fresh if the insect is to become introduced and established in this manner. The following experiments on the effects of the drying of the pupa cases of the insect on the emergence of the adults show what may be expected from parts of infested plants that have begun to dry out. These will also apply to the possibility of the insect becoming introduced on parts of plants mixed in shipments of fruits.

EXPERIMENT NO. 1.

Started May 10—Pupal stage.

Number of leaves—Seven leaves used in this experiment. These were kept in a 5½-inch covered petri dish. (Lime leaves.)

Number of pupæ—100 males and 200 females. Adults had been previously emerging from same colonies.

Remarks:

May 11—Two males and two females emerged.

May 12—Six males and eight females emerged.

May 13—Three males and six females emerged.

May 14—Two males and three females emerged.

May 15—Five males and six females emerged. Individuals having trouble getting out of pupa cases, due to dryness.

Remarks:

- May 16—Two males and two females emerged. One female unable to free itself from pupal skin. Died.
- May 17—Two males and one female emerged. One male died in attempts to free itself from pupal skin.
- May 18—No observations.
- May 19—One male and one female emerged. One male and one female died in attempting to emerge on May 18 (?). Leaves thoroughly dried out. They were very dry May 15.
- May 20—No emergence. A blotter was moistened with water and two drops of phenol put on it before it was placed in petri dish with leaves.
- May 21—No emergence. A number of pupæ looked normal, and further emergence was considered possible.
- May 27—Entire lot of leaves moldy. No further emergence, hence whole lot discarded and experiment finished.

EXPERIMENT NO. 2.

Started May 28, 1919—Pupal stage (early).

Number of leaves—Six, placed in petri dish, covered.

Number of pupæ—200 females, 50 males. No previous emergence.

Remarks:

- June 4—Leaves drying out, but not thoroughly dry. No emergence.
- June 6—Leaves thoroughly dry. No emergence.
- June 13—No emergence.
- June 15—No emergence.
- June 17—Pupæ carefully examined. Shriveled. All dead. Experiment discontinued.

EXPERIMENT NO. 3.

Number of pupæ—23 males and 32 females.

Leaves kept from May 11, 1919, to June 26, 1919, in bottle of water.

Remarks:

- June 26—One male emerged. Leaves badly wilted since June 23.
- June 30—One male emerged.
- July 4—One male emerged. Shoot all dried up, barely moist; leaves removed and put in covered petri dish for further observation.
- July 5—One female died in process of emergence. Moisture added to petri dish.
- July 6—One female died in process of emergence.
- July 8—One female emerged. One female died in process of emergence. Leaves thoroughly dried out.
- July 9—Leaves thoroughly dried. No further emergence. All pupæ examined and dead. Experiment discontinued.

EXPERIMENT NO. 4.

Number of pupæ—35 females and 46 males. Brought in from field. 15 males and 2 females had already emerged.

Started June 5, 1919—Put in petri dish.

Remarks:

- June 6—Four females and three males emerged. All in the morning.
- June 7—Four females and two males emerged. All in the morning.
- June 8—One female emerged in morning.

Remarks:

- June 9—Two females and two males emerged. All in the morning.
 June 10—One female and one male emerged. Both in the morning.
 June 11—No emergence; leaf thoroughly dry.
 June 12—One female emerging. T-shaped slip on pupa visible, but individual having trouble, due to dry conditions. Moisture added to petri dish.
 June 13—One female of June 12 died in emergence. T-shaped slit slightly spread open, indicating feeble attempt of individual to escape.
 June 14 to 20—No further emergence. Pupæ all dead on examination. Experiment discontinued.

EXPERIMENT NO. 5.

Number of pupæ—87 females and 18 males, from which 3 females and 2 males had emerged before these were brought to the laboratory on June 5, 1919, and were put in a petri dish.

Remarks:

- June 5 to 9—No emergence. Leaves very dry on June 9.
 June 10—One male emerged in morning.
 June 11—No emergence.
 June 12—One female emerging in morning. Moisture added.
 June 13—Female emerging June 12 died in process.
 June 14 to 20—All pupæ dead on examination June 20. Experiment discontinued.

The third of the methods outlined, namely, the bringing in of eggs on the fruits, seems to be a rather remote one. That the adults do lay eggs on the fruits under certain conditions has been demonstrated by Morrison (1917) and by the writers, and though the writers have failed to find this the case out of doors in the region where they have worked, they fully realize that it may take place. But the first-instar larvæ of *A. woglumi* are not like the larvæ of scale insects, as has been shown under the heading "Life history," p. 31. They are sluggish crawlers and have little ambition to wander far from the eggs from which they have hatched. Hence, even if the eggs on fruit would hatch the larvæ would either settle down on it or, if they fell off, would perish. The following experiment shows how remote the possibility of the insect being introduced in the egg stage and becoming successfully established really is.

In order to see if larvæ would migrate far the following experiment was tried: Two leaves bearing about 200 eggs each, from which larvæ were just beginning to hatch, were removed from a twig and tied to two leaves on a young tree in the laboratory. One was tied so that parts of its under surface rested against the under surface of the leaf on the tree and the other was tied so that its under surface rested against the upper surface of the leaf on the tree. Five days later, when the leaves bearing the eggs had completely dried out, an examination was made, and it was found that only four larvæ had crawled

over to the under surface of the leaf of the tree and only three had settled on the upper surface. On the two leaves that were tied to those on the tree a total of 65 larvæ had settled. An equal number were dead attached to the eggs, apparently having died in the attempt to escape from them, because of the drying out of the leaves, as is shown later. A week later all the larvæ that had migrated to the tree were dead.

In order to show the effects of the drying out of the leaves on the hatching of the eggs the following experiments are of interest:

EXPERIMENT NO. 1.

On July 12, 1919, a shoot on which adults were clustered was brought to the laboratory. Fifteen spirals were laid on three upper leaves of the shoot and ten on two lower ones. The shoot was placed in a bottle of water for observation.

In the 15 spirals were 387 eggs. In the 10 spirals were 187 eggs.

On July 23, 1919, the entire shoot was wilted, the upper leaves were not dry, but the lower ones were turning brown and drying out. These leaves were removed and put in covered petri dishes for observation.

On July 26, 1919, 340 out of the 387 eggs hatched (approximately 90 per cent), but only 30 of the 187 eggs had hatched on July 30 and the experiment was discontinued.

EXPERIMENT NO. 2.

Eggs on leaves brought into laboratory from the field July 23, 1919, still whitish in color, hence not over 24 hours old. Put in covered petri dish. Number of eggs, 71.

July 26—Eggs fully colored.

July 28—Leaves drying out.

August 1—Leaves thoroughly dry, eggs shriveled. Discarded.

EXPERIMENT NO. 3.

Eggs on leaves brought into laboratory from the field July 23, 1919; blackish in color, indicating that they were over 8 days old. Put in covered petri dish. Number of eggs, 335.

July 26—Eggs shriveling. Leaves wilted but moist.

July 28—Leaves drying out; no hatching.

August 1—Eggs shriveled. Leaves slightly moist. Discarded.

EXPERIMENT NO. 4.

Eggs on leaves brought into laboratory from field July 23, 1919; eggs dark brown in color, indicating that they were at least 3 days old and not more than 10 days old. Number of eggs, 173.

July 26—No hatching. Leaves wilted but moist.

July 28—No hatching. Leaves drying out.

August 1—Eight larvæ died in emerging. Rest of eggs shriveled. Leaves slightly moist. Discarded.

EXPERIMENT NO. 5.

Eggs on leaves brought into laboratory from field July 23, 1919; eggs brown in color, indicating that they were over 3 days old. Number of eggs, 141.

July 26—No hatching. Leaves wilted but very moist.

July 28—No hatching. Leaves drying out.

August 1—No hatching. Eggs shriveled. Leaves still slightly moist. Discarded.

The fifth possible means of introduction, namely, the bringing in of adults on freight cars from Cuba via the railroad ferry plying between Habana and Key West, is one worthy of consideration. The writers have seen what they believe to be "train borne" infestations at Miraflores and Frijoles, though there is no proof, except that all other possibilities were eliminated as far as practicable. In the first place, the infestation in the Canal Zone could be "train borne" much more easily than it could be carried from Cuba to Florida. Frijoles is about midway between Panama and Colon, or about an hour's run by train, while Miraflores is but 15 to 20 minutes distant from Panama. On the other hand, Habana is over 10 hours away from Key West with all the trip across the ocean. Whether the adults could weather such a trip is open to question. Again, in the Canal Zone the "train borne" infestation took place in a region where the insect had already successfully established itself. Doubtless if introduced at Key West or at the lower end of Florida, the black fly would, under proper conditions, become established, but whether it would be able to maintain itself in the more northern portions of the State is debatable for here there is a factor with which the writers have not had any experience in the Canal Zone or adjoining parts of the Republic of Panama. That factor is much lower minimum and mean minimum temperatures than are ever reached in the regions where *A. woglumi* now occurs.

Then too, if only unfertilized females were introduced the insect would die out after the first generation, for owing to parthenogenesis all the individuals would be males. And finally, the question of the influence of different climatic conditions, other than temperature, on the mortality in the various developmental stages of the insect comes into play. All in all there is at present nothing to warrant the idea that there is great danger of *Aleurocanthus woglumi* becoming introduced into and established in the United States through adults brought from Cuba on freight cars via the railroad ferry plying between Habana and Key West. The matter is one where there are two points of view. The removal of citrus and other host plants from the vicinity of the terminal freight yards and railroad sidings in Habana, however, would absolutely insure freight cars being free from *A. woglumi*.

In conclusion, the method by which the black fly is most apt to become introduced into the United States and through which it will have the greatest opportunity of becoming established in favorable localities, is on undefoliated, infested nursery stock of various kinds, or individual infested plants for ornamental or other purposes. This includes also undefoliated parts of plants like cuttings for propagation. This is the way it has spread from the Tropics of the Old World to those of the New and the way it has continued its spread over widely separated parts of its new home. Bragdon (5) has pointed out the

danger of the black fly being brought in on parts of infested plants by passengers returning from a country where the pest occurs.

SUMMARY.

The black fly, *Aleurocanthus woglumi*, was introduced into Jamaica from India on infested food plants within the last 10 to 15 years. From this focus in the New World it has spread to Cuba, New Providence, the Canal Zone, the Republic of Panama, and Costa Rica, and is continuing its spread from these new centers.

It was probably introduced into the Canal Zone between the years 1912 and 1914, the introduction taking place on more than one lot of infested food plants.

This report is based on an intensive study of this pest in the Canal Zone made from June, 1918, to August, 1919.

The introduction and establishment of this pest in widely separated areas has taken place through nursery stock or infested individual food plants, including cuttings for propagation. Within a region this method of spread is supplemented by the natural flight of the adults, by their carriage on vehicles and trains, and on the clothing of persons passing or working among infested trees.

The important food plants of this insect in the Canal Zone are: *Ardisia revoluta*, various species of the genus *Citrus*, *Coffea arabica*, *Eleais melanococca*, *Eugenia jambos* and *E. malaccensis*, *Lucuma mammosa* and *L. nervosa*, *Melicocca bijuga*, and *Mangifera indica*.

This insect, under certain conditions, injures seriously plants infested by it, but no plants killed by it have been found in the Canal Zone and Republic of Panama.

There are six stages in the life history of the black fly, namely, the egg, three larval instars, the pupa, and the adult. The life history is not clear-cut and there is a decided overlapping of stages. The length of time for the completion of one generation ranges from 45 to 113 days. The duration of the various stages are: Egg, 11 to 20 days; first larval instar, 7 to 16 days; second larval instar, 5 to 30 days; third larval instar, 6 to 20 days; pupa, 16 to 80 days; adult, probably 6 to 12 days.

There is a great mortality in the various stages, only 22.5 per cent of the individuals of 790 eggs reaching maturity.

The natural climatic factors that tend to hold the insect in check in the Canal Zone are: Drying out during the dry season and the heavy rains during the wet season.

Five species of coccinellids and one species of *Chrysopa* have been found to be predacious on the various stages of *Aleurocanthus woglumi* but they are not as yet sufficiently abundant to be important factors in its control. No internal parasites were found.

The black fly can be controlled by contact insecticides. Five and ten per cent kerosene emulsions, fish-oil soap at the rate of 1 pound to 2 and to 4 gallons of water, and nicotine oleate have given good results.

There is a possibility that this insect may gain entrance into and become established in the United States, particularly Florida. It already occurs in Cuba and Nassau, New Providence. The way in which it is most apt to be introduced and become established is through infested food plants, such as nursery stock or individual plants, or as cuttings for propagation. This is the way in which it was brought from the Old World to the New and is the way in which it is continuing its spread to widely separated parts of its new home.

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L. O. HOWARD, Chief



Washington, D. C.

October 21, 1920

SPOTTED APPLE-TREE BORER.

By FRED E. BROOKS, *Entomologist, Deciduous-Fruit Insect Investigations.*

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INTRODUCTION.

In connection with a study made by the Bureau of Entomology, under the general direction of Dr. A. L. Quaintance, of several insects whose larvæ bore in the bark and wood of deciduous fruit trees, attention has been directed to the cerambycid species *Saperda creata* Newman, known commonly as the spotted apple-tree borer. This insect occurs locally throughout the apple-growing sections of the central and eastern parts of the United States and is closely allied in habitat, appearance, and behavior with the roundheaded apple-tree borer (*Saperda candida* Fab.) The appellation "spotted" refers to the large white spots on the back of the adult (Pl. II, A-D.) and was probably suggested in contradistinction to the longitudinal dorsal stripes of its better known congener referred to above.

The spotted apple-tree borer appears to be entirely absent from many localities within its general range, while in other localities it is abundant, occasionally replacing to a great extent the roundheaded species. In the vicinity of Lansing, Mich., the writer found it outnumbering *Saperda candida* probably fifty to one. Prof. R. H. Pettit, State entomologist of Michigan, in a letter written in 1916, states that about the Michigan Agricultural College they have taken the beetles in so many places and in so many ways that their capture has ceased to excite comment. In certain parts of Iowa and Wisconsin the species has also been reported as common.

The account which follows is based largely on observations of specimens collected as 1-year-old larvæ in Michigan in 1916 and 1917 and transported in the wood to West Virginia, where they were removed from their feeding places and planted in the trunks and branches of living apple trees of various sizes. In their new position the larvæ continued without intermission to feed, and, so far as could be observed, the insects developed and functioned normally. In the way described a considerable number of adults were reared and from these numerous eggs and future stages of the insect were obtained for life-history study.

HISTORY AND DISTRIBUTION.

The spotted apple-tree borer was first described by Edward Newman in 1838 ¹ under the systematic name which it still bears. The



FIG. 1.—Distribution of the spotted apple-tree borer. Dots represent definite localities and crosses represent States in which found.

first reference in literature to the habits of the species can probably be accredited to L. J. Templin, who, writing in 1877, ² spoke of injury to apple trees in the West, evidently by this species. In 1880 Prof. Henry Osborne ³ described injury by this insect to apple trees in Iowa, and in 1881 Prof. A. J. Cook ⁴ wrote of serious injury by the spotted apple-tree borer in Michigan.

The following definite locality records have been obtained from museum specimens, from the notes of collectors, and from observations made during the present investigations: Tyngsboro, Mass.; Philadelphia, Pa.; Highfield, Md.; French Creek, W. Va.; Lansing, East Lansing, and Detroit, Mich.; Milwaukee, Wis.; Charles City, Manchester, Ames, and Iowa City, Iowa; Edgebrook, Glen View, and Palos Park, Ill.; Beaumont, Tex., and Paris, Ontario, Canada. The species is recorded also from New York, New Jersey, and Ohio. The map (fig. 1) shows the distribution of the insect, so far as known at present, in the United States and Canada.

¹ NEWMAN, EDWARD. ENTOMOLOGICAL NOTES. *In* Ent. Mag., v. 5, p. 395-396. 1838.

² TEMPLIN, L. J. *In* Practical Farmer. Nov. 17, 1877.

³ OSBORNE, HENRY. *In* Western Stock Jour. and Farmer, v. 10, p. 273-274. 1880.

⁴ COOK, A. J. CARBOLIC ACID AS A PREVENTIVE OF INSECT RAVAGES. *In* Can. Ent., v. 13, p. 189-191. 1881.

FOOD PLANTS.

At East Lansing, Mich., the writer found larvæ of the spotted apple-tree borer in abundance in cultivated and roadside seedling apple trees and rather less abundantly in wild crab apple and *crataegus* trees. Of the three hosts wild crab apple was apparently least preferred. In a letter to the author written in 1916 by Mr. A. B. Wolcott, of the Field Museum of Natural History, Chicago, Ill., it is stated that Mr. Emil Liljeblof has taken the beetles in Illinois from June 12 to July 20 on several species of *Crataegus*. Chittenden¹ says: "Apple and wild crab are the only plants which it has been observed to injure, but its occurrence has been noted on juneberry and thorn." Slingerland and Crosby² give apple, wild crab apple, juneberry, and thorn as the host plants. The present writer has never found the species attacking juneberry.

NATURE OF INJURY.

The injury done by this borer is very similar to that of the common roundheaded species, except that it usually occurs higher on the tree. The common borer almost invariably attacks near the ground, whereas the spotted species distributes its wounds along the central and upper portions of the trunk and among the branches. Small trees and branches, an inch or two in diameter, are most liable to attack. Old wounds made by the borers are frequently marked by slight swellings on the surface, having more or less of a gall-like appearance. Sawdust-like castings are thrown out freely from the burrows.

The borers hatch from eggs that are placed between the bark and wood at the side of punctures which the adult female makes through the bark with her mandibles. As has been pointed out by Osborne,³ in some cases two eggs are placed on opposite sides of a puncture. Of the numerous egg punctures examined by the writer, about half contained two eggs and the other half only one.

The larva on hatching begins to feed between the bark and wood, eating out an irregularly shaped space at the side of the oviposition scar, meantime thrusting most of its castings out at the opening through which the egg was inserted. The burrow is usually made to extend gradually away from the original scar, and, where two eggs occur, the resultant larvæ sometimes eat in opposite directions around the branch until their burrows meet, thus forming a more or less complete girdle. Toward the end of the first season or in the spring of the second season the larva enters the wood, and, by means

¹ CHITTENDEN, F. H. THE LARGER APPLE-TREE BORERS. U. S. Dept. Agr., Div. Ent., Circ. 32., p. 7, fig. 2. 1898.

² SLINGERLAND, M. V., and CROSBY, C. R. MANUAL OF FRUIT INSECTS, p. 193-194, fig. 185. 1914.

³ OSBORNE, HENRY, op. cit.

of an irregular, tortuous burrow, works its way to the heart of the branch. In the heart it burrows up and down for a distance of from 4 to 6 inches (Pl. IV, A), finally making at the upper end of the burrow a curved extension outward to the inner bark (Pl. I, E, F). Through this the beetle escapes later by gnawing a circular exit in the bark (Pl. V, A, C). Badly infested trees take on a sickly, scraggly appearance, individual branches, and occasionally small trees, dying from the injury.

LIFE HISTORY.

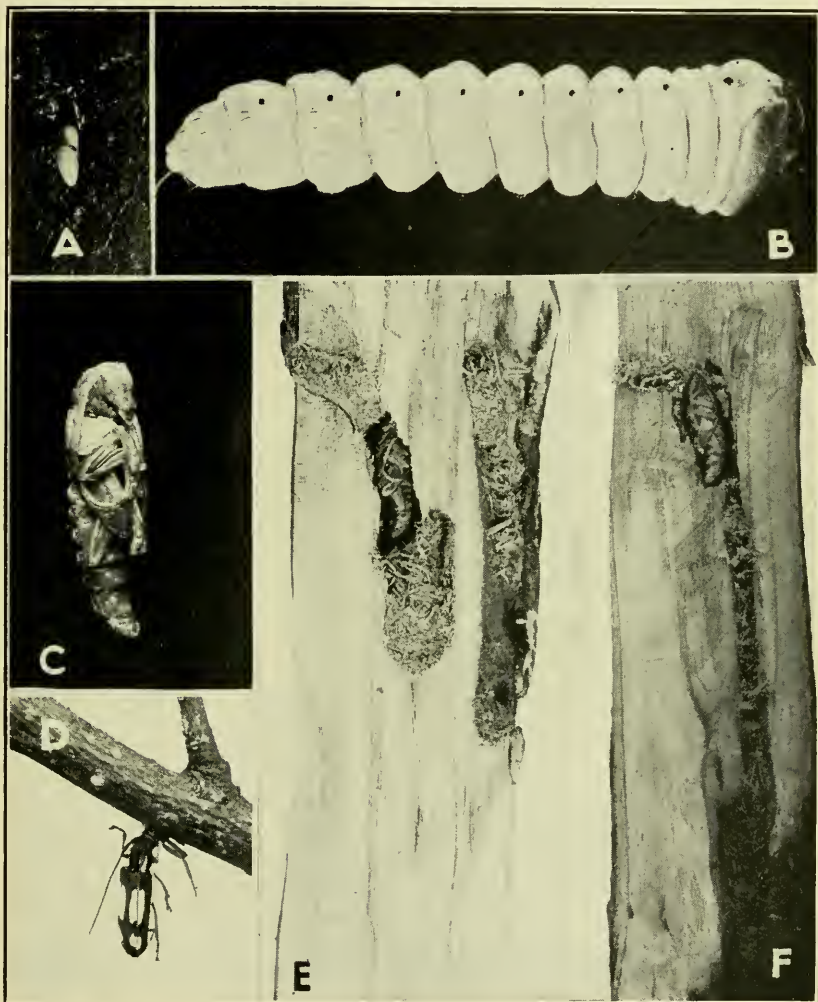
The beetles issue from the wood by day in spring and early summer. In West Virginia they have been observed to appear from May 14 to 31. At East Lansing, Mich., the beetles had apparently all issued on June 26, 1916, but the year following (1917) in the same locality all maturing individuals were still in the pupa stage on June 15.

As would be expected, the beetles appear earlier in the South than in the North. There is probably a variation in the time of emergence of several weeks between the southern and northern limits of the species' range.

After emergence the beetles seek the foliage of the trees and feed, at times rather freely, on the bark of twigs and leaf petioles, and, occasionally, on the leaves (Pl. V, D). Copulation did not take place with any of the beetles observed until about two weeks after emergence. About a week after the first copulation, or three weeks after emergence, oviposition began. Eggs may be laid by an individual female over a period of at least 60 days. The eggs are placed between the bark and wood (Pl. II, E), and hatch in about three weeks. In some cases the larval period is two years, in others three years, and, occasionally, it covers four years. The full-grown larvæ change in the spring to pupæ, which occupy an open space at the upper end of an elongate burrow, usually in the heart of a small trunk or branch (Pl. I, E, F; Pl. IV, B). The pupa stage lasts from four to six weeks. After transforming to adults the insects remain within the pupal cell for from one to two weeks and then gnaw their way out through the bark.

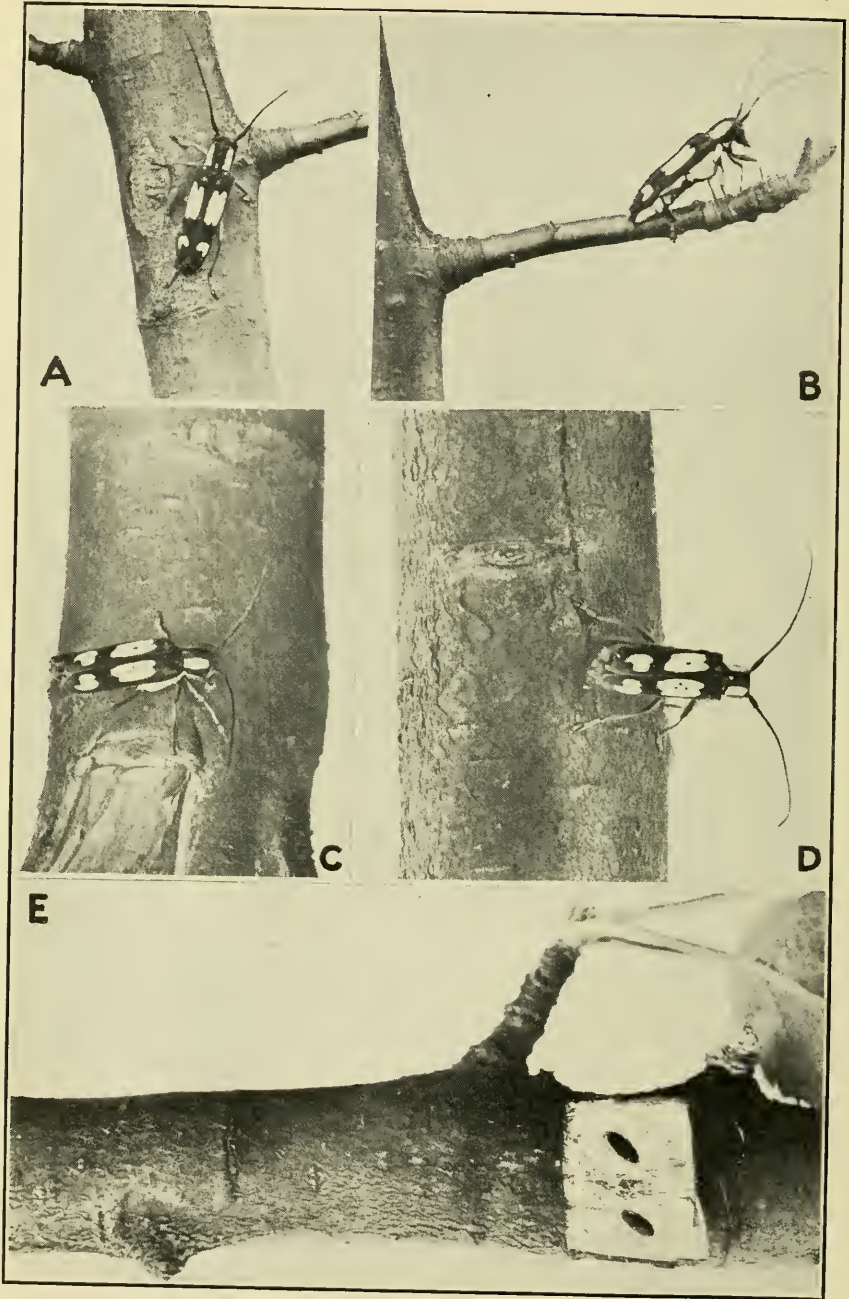
THE EGG.

The egg is elongate, plastic, creamy-white when first laid, but changing to light brown within a few hours. (Pl. I, A; Pl. II, E.) Several specimens removed from their position beneath the bark averaged 4 mm. in length by 2 mm. in width. They were flattened, bluntly rounded at the ends, the surface finely granular and marked by impressions of the wood fiber which pressed them closely on both sides. A free egg found in an oviposition scar was fusiform, slightly curved, both ends tapering to rounded points, 3.7 mm. in length by 1 mm.



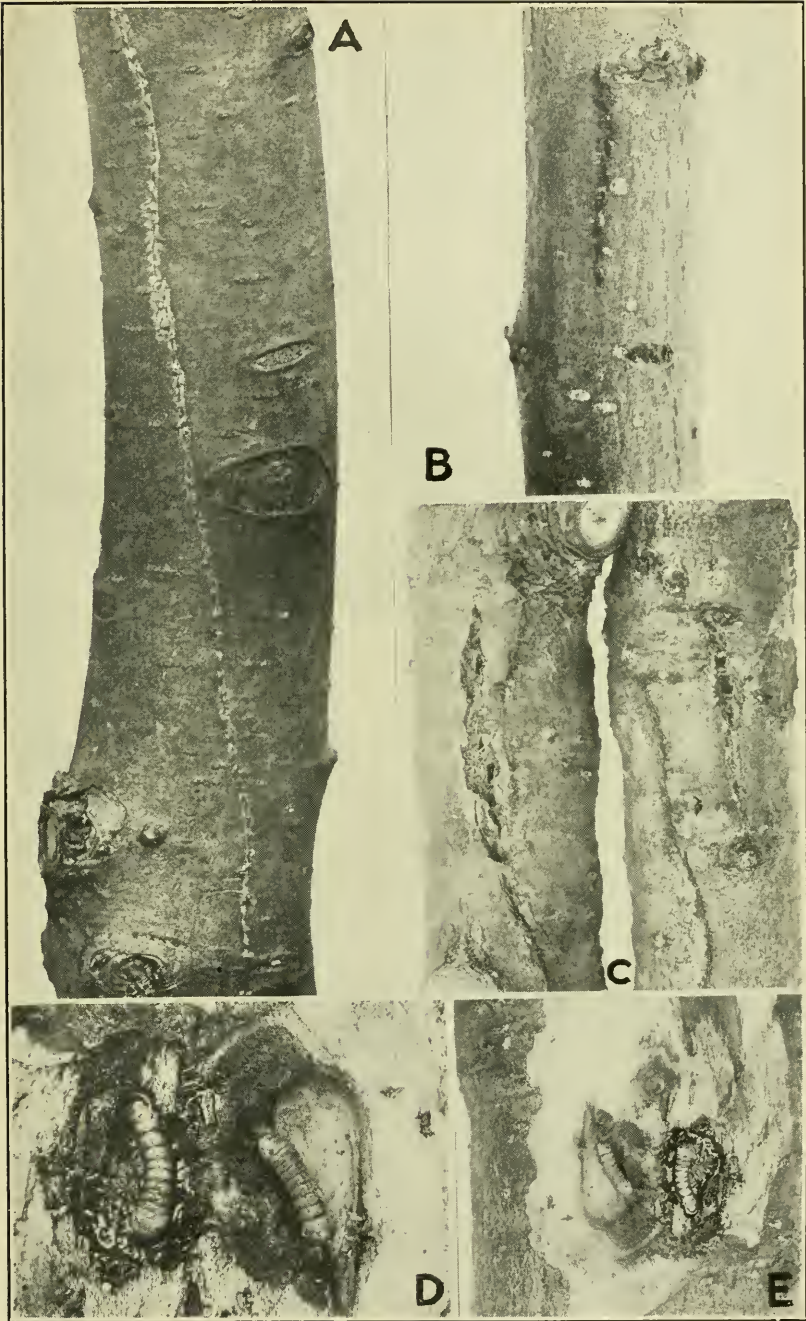
STAGES OF SPOTTED APPLE-TREE BORER.

A, Egg projecting from apple bark; an unusual position; much enlarged. *B*, Larva; much enlarged. *C*, Pupa; much enlarged. *D*, Adult of borer killed by and held in jaws of spider. *E*, *F*, Pupæ in natural position in apple wood.



ADULTS AND EGGS OF SPOTTED APPLE-TREE BORER.

A, B, Adult female resting on apple branches; slightly enlarged. *C*, Female beetle in act of preparing egg puncture in apple bark; slightly enlarged. *D*, Female beetle in act of oviposition; slightly enlarged. *E*, Apple bark removed to show eggs in natural position.



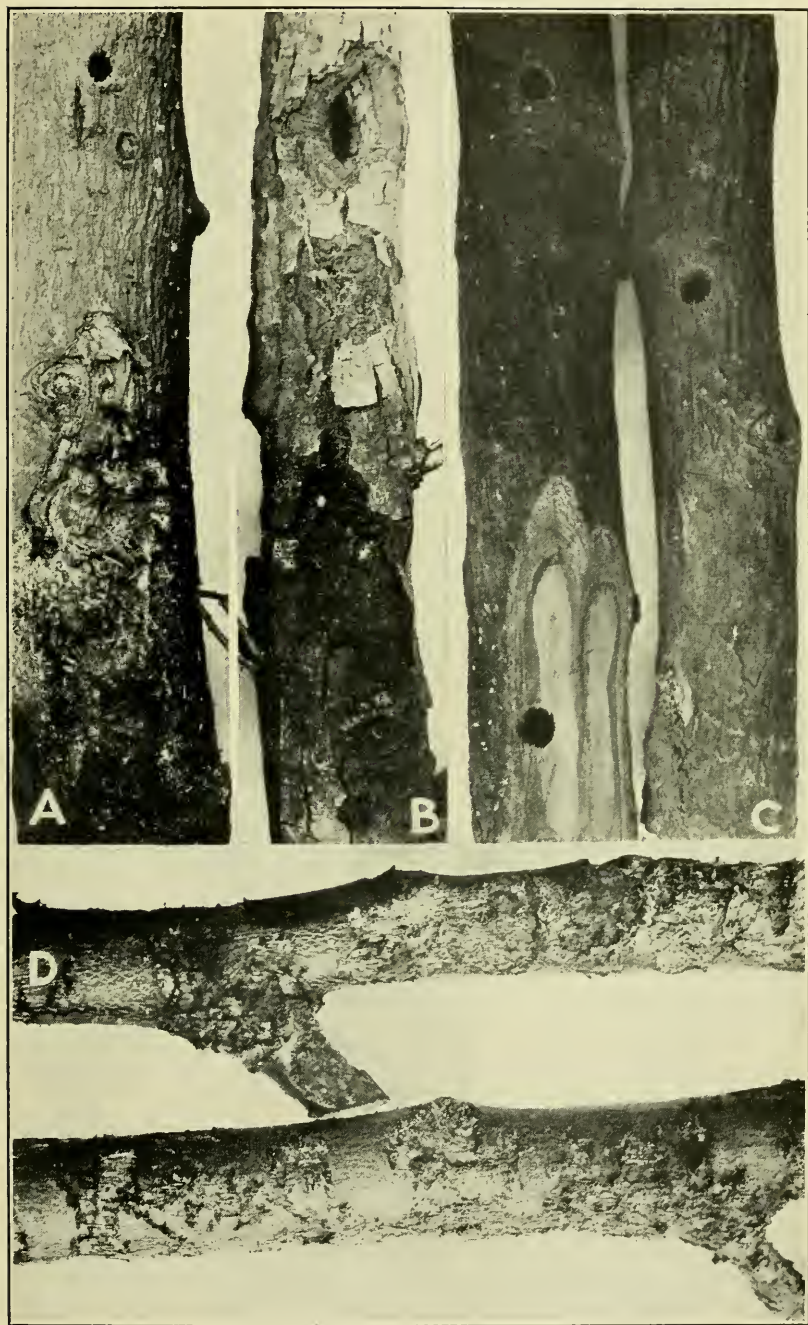
OVIPOSITION SCARS AND LARVÆ OF SPOTTED APPLE-TREE BORER.

A, Long chain of punctures in apple bark accompanying oviposition scar. Eggs were deposited at broad place in chain slightly above the center. B, Short chain of punctures accompanying oviposition scar. C, Other forms of oviposition scars. D, E, Pairs of young larvæ found in oviposition scars.



WORK OF SPOTTED APPLE-TREE BORER.

A, Nearly mature larva working in heart of apple wood; natural size. B, Pupa occupying natural position at upper end of gallery in heart of apple wood; slightly enlarged. C, Section of trunk of young apple tree having a swollen and roughened appearance as a result of injury by borers.



WORK OF SPOTTED APPLE-TREE BORER.

A, Wound of borer and exit hole of adult; natural size. B, Wound made by woodpeckers in removing borer from apple wood. C, Exit holes of adults; natural size. D, Apple twigs showing bark gnawed off by beetles.

in width at the widest point. Eggs in normal position are surrounded by a waxy semitransparent substance, which excludes air and probably shuts out natural enemies.

The eggs are placed between the bark and wood at the side of vertical slits in the bark which the female beetle makes with her jaws. (Pl. III, A, B, C.) These slits, or oviposition scars, may be along the central or upper portions of the trunk or in the branches. They are often accompanied by a chain of shallow punctures extending above and below the oviposition scar, the line of marks resembling the impression that would be made by pressing the cutting edge of a fine-toothed saw against the bark. (Pl. III, A.) In some cases only one egg is placed in a slit and in other cases a pair are deposited, one on each side of the opening. The eggs occupy an oblique position to the line of punctures and are thrust back under the bark from 2 to 3 mm. from the slit at the nearest point. (Pl. II, E.) Four eggs laid on June 29 were kept under observation until July 20 and were then lost by accident, apparently as they were just ready to hatch. This indicates a period of incubation of something over three weeks.

THE LARVA.

The larva (Pl. I, B; Pl. III, D, E; Pl. IV, A) is a whitish, deeply segmented, footless, sparsely bristled grub, having a brown head with black jaws and a broad, convex, papillose, shield-like plate on the dorsum of the prothorax. Full-grown larvæ are from 25 to 30 mm. in length and about 5 mm. in width at the prothorax. The prothoracic segment is widest, the segments tapering to the fourth, and from there being uniform in width to the twelfth. The thirteenth segment narrows to a blunt point. To the casual observer the larva of this species is indistinguishable from that of *Saperda candida*.

In the latitude of West Virginia the larvæ hatch and begin feeding at any time from the latter part of July until some time in September. During the first season the larval excavations are in the form of more or less circular or roughly elongate burrows on one or both sides (according to whether there are one or two larvæ present) of the oviposition scar. (Pl. III, D, E.) At first fine, sawdust-like castings issuing from the oviposition scars mark the presence of the feeding borers.

The second season the borer enters the wood, forming a ragged, winding burrow that leads ultimately to the heart. Here, in the center of the wood, it mines, usually going upward 5 or 6 inches, where it finally pupates at the upper end of the gallery, after having terminated its burrow with an abrupt curve outward to the inner bark. (Pl. I, E, F; Pl. IV, A, B.) As the borer feeds it ejects part of its castings through the bark and packs the rest in unoccupied corners of its burrow. The burrow below the pupal chamber is

packed for an inch or two with excelsior-like strings of wood (Pl. IV, B), evidently as a safeguard against the accumulation of too much moisture while the insect is undergoing its transformation to the adult stage.

Probably the behavior and the metamorphic development of this species are affected to a considerable extent by differences in latitude. No doubt the borer feeds more extensively and grows more rapidly the first season in the South than in the North. In West Virginia, of 16 individuals in which the duration of the larval period was observed, 1 lived in the tree 2 years, 14 lived 3 years, and 1 lived 4 years.

THE PUPA.

The pupa (Pl. I, C, E, F; Pl. IV, B) is characteristic of the family, being creamy white in color with the rudimentary legs, wing pads, and antennæ folded close to the body. In form it is slender, averaging 17 mm. in length by 5 mm. in width. The dimensions of the cell which it occupies (Pl. I, E, F; Pl. IV, B) are only slightly greater than those of the pupa itself. The average size of this cell is about 20 by 8 mm. The restricted quarters of the pupa limit its movements much more than is the case with the pupa of the common borer, *Saperda candida*, whose pupal cell may be 2 inches or more in length. In West Virginia pupation takes place in April, one specimen being found in the pupa stage on April 3. The pupal period lasts from four to six weeks. This stage, also, of the insect's development is probably affected in time limits by differences in climatic conditions due to latitude.

THE ADULT.

The adult of this borer (Pl. II, A-D) is a handsome beetle, the females of which are from 15 to 20 mm. and the males from 12 to 16 mm. in length, the females being much more robust than the males. The upper parts are cinnamon brown with a broad white stripe on each side of the thorax, a large, oblong, white spot, notched at the ends, on the middle of each elytron, and a smaller, comma-shaped, white spot midway between each of these and the apex. There are usually a minute white spot on the thorax just in front of the scutellum and one each on the humeral angles. The sides are white and the underparts of the abdomen and thorax, and the head, antennæ, and legs are brown.

After transforming, the beetles remain in their pupal quarters for several days to harden and then escape by gnawing a circular hole through the bark barrier that has shut them in. (Pl. V, A, C.) The exit hole in the bark is from 5 to 6 mm. in diameter, that of the male being smaller than that of the female.

On escaping, the beetles seek seclusion among the branches where they rest in comparative inactivity during the brighter part of the

day. Near evening they become more active, flying, feeding, copulation, and oviposition being engaged in most freely about sundown, although all these activities extend into the night. The beetles feed rather freely on the tender bark, a favorite place for feeding being the thickened bark around the base of small twigs.

TIME OF EMERGENCE OF BEETLES.

According to Osborne,¹ the beetles appear in Iowa about the middle of June. Wolcott states, in correspondence with the writer, that the beetles have been taken in Illinois from June 12 to July 20. In 1916 the writer found that apparently the last of the beetles had emerged at East Lansing, Mich., on June 26. On June 15, 1917, however, emergence had not yet begun in the same locality. At French Creek, W. Va., beetles issued in 1919 from May 14 to 31, as indicated in Table I.

TABLE I.—*Time of emergence of beetles of the spotted apple-tree borer at French Creek, W. Va., in 1919.*

Date.	Number of beetles.		
	Males.	Females.	Total.
May 14.....	1	0	1
15.....	1	0	1
19.....	2	0	2
20.....	1	0	1
22.....	1	0	1
24.....	1	0	1
25.....	1	0	1
26.....	2	1	3
27.....	1	1	2
28.....	0	1	1
29.....	0	1	1
31.....	0	1	1
Total.....	11	5	16

It appears from the foregoing data that emergence may take place from the first of May to the last of June, according to locality and climatic conditions. It is very probable that the beetles appear before the first of May in the more southerly localities of the species' range.

OVIPOSITION.

The interesting process of oviposition begins a week or two after the eggs are fertilized. As has been stated, the female usually selects the upper part of the trunk of young trees or branches an inch or two in diameter in which to place her eggs. Occasionally the oviposition scar is in the form of a small, somewhat circular opening in the bark, but more frequently it is a deep, narrow gash in the bark, often accompanied with a more or less prolonged line of pricks extending vertically from one or both ends of the gash. (Pl. III, A-C.)

¹ Osborne, Henry, op. cit.

Oviposition was observed repeatedly and the following may be given as a typical example of one of the more elaborate operations attending the act: About an hour before sundown a beetle was observed to take a horizontal position across the trunk of a young apple tree, about 30 inches above the ground. She began at once to force her jaws their full length into the tender bark. (Pl. II, C.) After the jaws were inserted and withdrawn, the beetle moved sidewise up the trunk for a short distance and again inserted them and thus continued the operation until she had a straight line of pricks about 2 mm. apart. When the line was about 2 inches long she joined several of the pricks together with a deeper furrow and then turned around, as though on a pivot, and inserted the tip of her abdomen into the opening. (Pl. II, D.) She then spent nine minutes in forcing her ovipositor forward between the bark and wood, after which she withdrew her ovipositor, reversed ends, moved across to the other side of the opening and then consumed an equal period of time in again inserting her ovipositor. The two eggs having been placed on opposite sides of the opening, the beetle then took her original position and continued making the chain of pricks until the line was 5 inches in length. She then crawled back among the branches of the tree.

When the oviposition scar was examined closely the two openings where the ovipositor had been thrust in were visible, both being filled with a brownish, semitransparent substance resembling wax. Occasionally a series of punctures is found in which there occur two of the oviposition furrows, each having one or two eggs.

LENGTH OF LIFE OF BEETLES.

Most of the beetles kept for observation were confined in roomy wire-screen cages placed over young apple trees in the field. In this position their length of life was probably something near normal. About one-half of the beetles died within a month after emergence, but a few lived for a considerably longer period. One male attained an adult age of 52 days, while a female lived 93 days. The latter individual died on August 30 and continued to oviposit up to within a few days of its death.

NATURAL ENEMIES.

By far the most effective natural check to the increase of this borer seems to be the woodpeckers. The borers feed in positions easily accessible to these birds and empty burrows are to be found on almost every infested tree, with the marks of the birds around the wounds giving unmistakable evidence of the cause of the borer's disappearance. (Pl. V, B.) During the present studies every attempt to rear larvæ in unprotected trees met with a loss of all the individuals as a result of woodpecker attack. The species of bird

responsible for the loss of the borers was not determined definitely, but all the evidence pointed to the downy woodpecker, *Dryobates pubescens medianus*. It seems probable that the spotted apple-tree borer would be a much more widely known and destructive pest were it not for the constant depletion of their numbers by woodpeckers.

On one occasion a newly emerged female beetle was found in one of the rearing cages hanging suspended in the jaws of a spider. (Pl. I, D.) The spider was captured and was determined later by Mr. C. R. Shoemaker as *Xysticus ferox* (Hentz).

In several cases in Michigan larvæ of the clearwing moth *Aegeria pyri* Harris were found as the sole occupants of burrows made recently by spotted apple-tree borers. There was good reason to believe that the larvæ of the moth had devoured the original occupants, but this could be considered only as an incidental occurrence.

METHODS OF CONTROL.

There is little doubt that in apple orchards which are sprayed with arsenicals for the codling moth and other common insect pests, many of the adults of this borer may be killed incidentally. The fact that beetles feed rather freely on exposed surfaces, especially on the wrinkled bark at the base of twigs where deposits of the poison from sprays collect and adhere, makes them susceptible to this means of control. The beetle has a rather prolonged feeding period before oviposition begins, and this affords a chance to kill it with poison sprays before it has provided for a succeeding generation of borers.

The borers, while small, may be found and removed from the trees very readily by paring away the bark over their burrows with a sharp knife. The burrows can be located without much trouble by the conspicuous castings which are thrown out, and also by the swollen, cankerlike appearance of the affected wood. (Pl. IV, C.) Badly infested branches can often be removed without injury to the tree, and the borers within be destroyed by burning. Breeding places, such as are provided by neglected seedling apple trees, and thorn and wild crab apple thickets, should not be allowed to remain in the immediate vicinity of cultivated orchards.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 887

Contribution from the Bureau of Entomology.
L. O. HOWARD, Chief.



Washington, D. C.



September 29, 1920

PEAR BORER.¹

By FRED E. BROOKS, *Entomologist, Deciduous-Fruit Insect Investigations.*

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INTRODUCTION.

The common name "pear borer," long ago bestowed upon the insect which forms the subject of this bulletin, is something of a misnomer, since the species attacks apple more extensively than pear. The name "apple crotch-borer" would be much more suggestive of the general habits of the insect. The species occurs over the eastern portion of the United States and in this region a few of the larvæ usually may be found boring in the bark of almost any old apple tree that may be examined. So long as the attack is limited to only a few borers the effect on the general health of the tree is scarcely perceptible, but occasionally the insects concentrate in certain trees and there breed in numbers year after year. The injury which follows is cumulative, resulting in depleted vigor, and often in the death of a part or all of the tree. On the whole, this borer is more injurious than is commonly supposed.

The following pages contain an account of this insect which is based very largely upon data collected by the Bureau of Entomology during the past five years. In gathering the data several badly infested apple orchards in Pennsylvania, West Virginia, and Mississippi were visited for the purpose of noting the extent of injury, conducting biological studies, and testing methods of control.

¹ *Aegeria pyri* Harris; order Lepidoptera, family Aegeriidae.

HISTORY AND DISTRIBUTION.

The pear borer is a native American insect that was first described by Dr. Thaddeus W. Harris² in 1830. It is rather widely distributed in the eastern part of this country, having been recorded from the following States: Maine, New York, New Jersey, Pennsylvania, Michigan, Maryland, West Virginia, Virginia, North Carolina, South Carolina, Georgia, Mississippi, Alabama, Missouri, and Texas. The species no doubt occurs in several States not included in the foregoing list.

SYNONYMY.³

Aegeria pyri Harris, New England Farmer, v. 9, 1830, p. 2; Amer. Journ. Arts & Sciences, v. 36, 1839, p. 313; Ins. Inj. Veget., 1841, p. 235; *ibid.*, 2d ed., 1852, p. 256; *ibid.*, 3d ed., 1862, p. 335; Harris's Corresp. (Scudder), 1869, p. 361; Walker, Cat. Lepid. Brit. Mus., Pt. VIII, 1856, p. 45; Packard, Guide Study Insects, 1869, p. 278 (and other editions); Thomas, 1st Rept. Nox. Ins. Illinois, 1876 (1878), p. 40; *ibid.*, 2d Rept. 1877 (1878), p. 170; Stout, Rept. Kansas Hort. Soc. 1879 (1880), p. 88; Martin, Thomas's 5th Rept. Nox. Ins. Ill. 1880 (1881), p. 107; Kellicott, Can. Ent., v. 13, 1881, p. 8; Grote, Check List N. Am. Moths, 1882, p. 12; Weed, Am. Nat., v. 23, 1889, p. 1108, fig.; U. S. Dept. Agr., Div. Ent., Ins. Life, v. 4, 1891, p. 34; Saunders's Ins. Inj. to Fruit, 1883, p. 140, fig. 146; *ibid.*, 2d ed., 1889, p. 140; Riley, Proc. Ent. Soc. Wash., v. 1, 1888, p. 85; Beutenmüller, Ann. N. Y. Acad. Sci., v. 5, 1890, p. 204.

Trochilium pyri Fitch, 3d Rept. Nox. Ins. N. Y., 1856, p. 349; Morris, Synop. Lepid. N. Am., 1862, p. 141.

Sesia pyri Boisduval, Suites à Buffon, Nat. Hist. Lepid. Het., v. 1, 1874, p. 440; Smith, Cat. Ins. N. J., 1890, p. 289; Beutenmüller, Bul. Am. Mus. Nat. Hist., v. 8, 1896, p. 139; *ibid.*, v. 9, 1897, p. 220; Beutenmüller, Memoirs Am. Mus. Nat. Hist., v. 1, Pt. VI, 1901, p. 297.

Aegeria koebelei, Henry Edwards, Papilio, v. 1, 1881, p. 196; Grote, New Check List N. Am. Moths, 1882, p. 12; Beutenmüller, Bul. Am. Mus. Nat. Hist., v. 4, 1892, p. 173.

FOOD PLANTS.

Larvæ of the pear borer have been found commonly attacking pear and apple. Dr. J. B. Smith⁴ records mountain ash (*Sorbus americana*) as a host plant. The writer has found the larvæ attacking juneberry (*Amelanchier canadensis*) and thorn (*Crataegus* sp.), and in black knots caused by *Plowrightia morbosa* on wild and cultivated cherry (*Prunus* spp.).

NATURE OF INJURY.

Injury is done by the larvæ feeding in the bark (Pl. II, B), the burrows occasionally extending slightly into the sapwood. In infested orchards particular trees on which the moths deposit most of their eggs year after year usually occur. This preference for certain trees

² HARRIS, T. W., INSECTS. In New England Farmer, v. 9. (1830-31), no. 1, p. 1-2, July, 1830.

³ The writer desires to express his thanks to Messrs. P. W. Mason and August Busck, of the Bureau of Entomology, for compiling and approving the synonymy as presented, and to Mr. Mason for supplying notes on the history, distribution, and food plants of the species under consideration.

⁴ SMITH, J. B. REPORT OF THE INSECTS OF NEW JERSEY. In Ann. Rept. N. J. Sta. Museum for 1909, p. 519. 1910.

is probably due chiefly to the fact that the continuous working of generations of larvæ in the bark causes a roughened surface (Pl. II, A, C) which is attractive to the ovipositing adults. Injury may occur at almost any point above the ground, except on the smaller twigs.

Larvæ are commonly found feeding in the crotches and in places where there is a rough or broken surface caused by the previous feeding of their own kind or by other agencies. (Pl. II, A, C; Pl. III.) Favorite places of attack are around the borders of mechanical wounds in the bark, areas affected by sun scald and winter injury, and around the burrows of other species of borers. The larvæ often develop within the excrescences of stem tumor (*Bacterium tumefaciens*) and black knot (*Plowrightia morbosa*), and about the borders of dead areas caused by pear blight (*Bacillus amylovorus*). The writer has found pear borers attacking trees under the following conditions: In stem tumor of apple at Quincy, Pa., Adrian, W. Va., Demorest, Ga., Gadsden, Ala., and Love Station, Miss.; in black knots on cultivated cherry and wild cherry (*Prunus virginiana*) at French Creek, W. Va., and Winthrop, Me.; in wounds made by roundheaded apple-tree borers (*Saperda candida* Fab.) in cultivated apple and juneberry trees (*Amelanchier canadensis*) at French Creek, W. Va., and Biltmore, N. C.; in wounds made in cultivated apple and wild thorn trees (*Crataegus* sp.) by the spotted apple-tree borer (*Saperda cretata* Newm.) at French Creek, W. Va., and East Lansing, Mich.; in wounds made in apple trees by the flatheaded apple-tree borer (*Chrysobothris femorata* Fab.) at French Creek, W. Va.; in wounds made in apple bark by the yellow-bellied sapsucker (*Sphyrapicus varius varius*) at Moorefield, W. Va., and Demorest, Ga.; and in the edges of wounds made in the operation of grafting apple trees at Lancaster and Quincy, Pa., and French Creek, W. Va. Where the larvæ were feeding in the position last named they were interfering seriously with the union of stock and scion. Mr. E. B. Blakeslee, of the Bureau of Entomology, in notes furnished to the writer, states that at Winchester, Va., pear borers have been observed to complete the girdling of apple trunks partially encircled by collar blight.

The damage done by a single borer is usually negligible, but the combined injury of a dozen or more borers may endanger the health or life of the tree. Often infested areas will occur at the upper part of the trunk where a number of branches originate (Pl. II, A, C) and the branches will die one by one until the tree is ruined. Badly infested trees usually take on a scraggly, neglected appearance, the bark being rough and the growth slow. (Pl. III.) Several orchards were visited during the present investigation in which it was not unusual to find from a dozen to a hundred borers working in a single tree. Under such conditions treatment of some kind for saving the trees is necessary.

THE EGG.

The egg (Pl. I, A) is light glossy brown, oval, and flattened. One end is slightly truncate and one side distinctly concave, the depressed area being elongate and covering half the central surface of the side. Length 0.6 mm., width 0.3 mm.

THE LARVA.

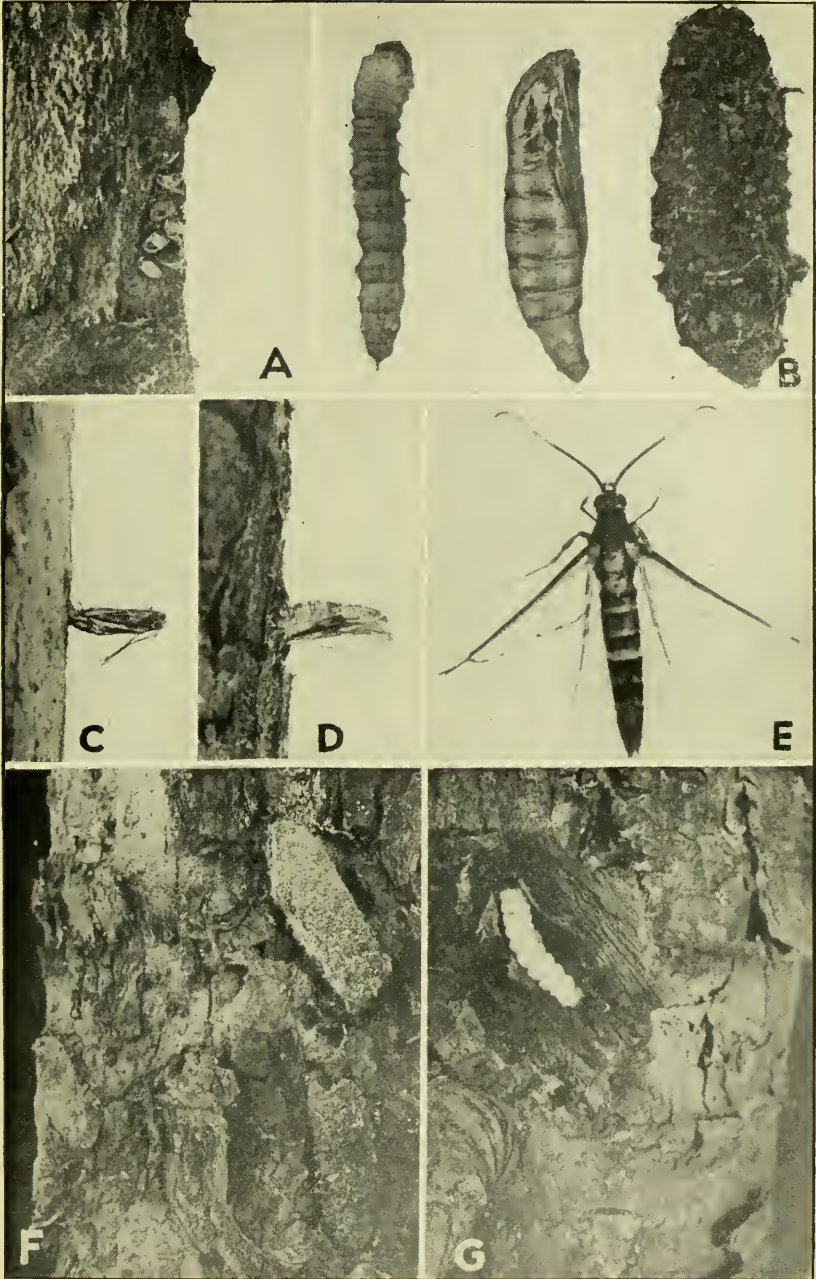
The larva (Pl. I, B, G; Pl. II, B, D) is creamy white with a brown head, the average length of full-grown specimens being about 15 mm. and the width slightly more than 2 mm. The thoracic and abdominal segments from the first to the tenth are uniform in width. Segments 11, 12, and 13 taper abruptly to a blunt point. Throughout, the body is very sparsely clothed with short, stiff hairs.

The larvæ feed almost exclusively on the inner bark, although occasionally, where the bark is thin, they will gnaw slightly into the sapwood. When feeding in the excrescences of black knot or stem tumor they penetrate into all parts of the porous tissue; also, after feeding at the edge of dead areas on the tree, full-grown borers sometimes penetrate into near-by decaying wood to construct their cocoons. Usually, however, feeding is confined to the bark of the trunk and larger branches.

The completed burrows vary greatly in shape, but are usually in the form of broad, elongate, central spaces with short galleries leading off in different directions.

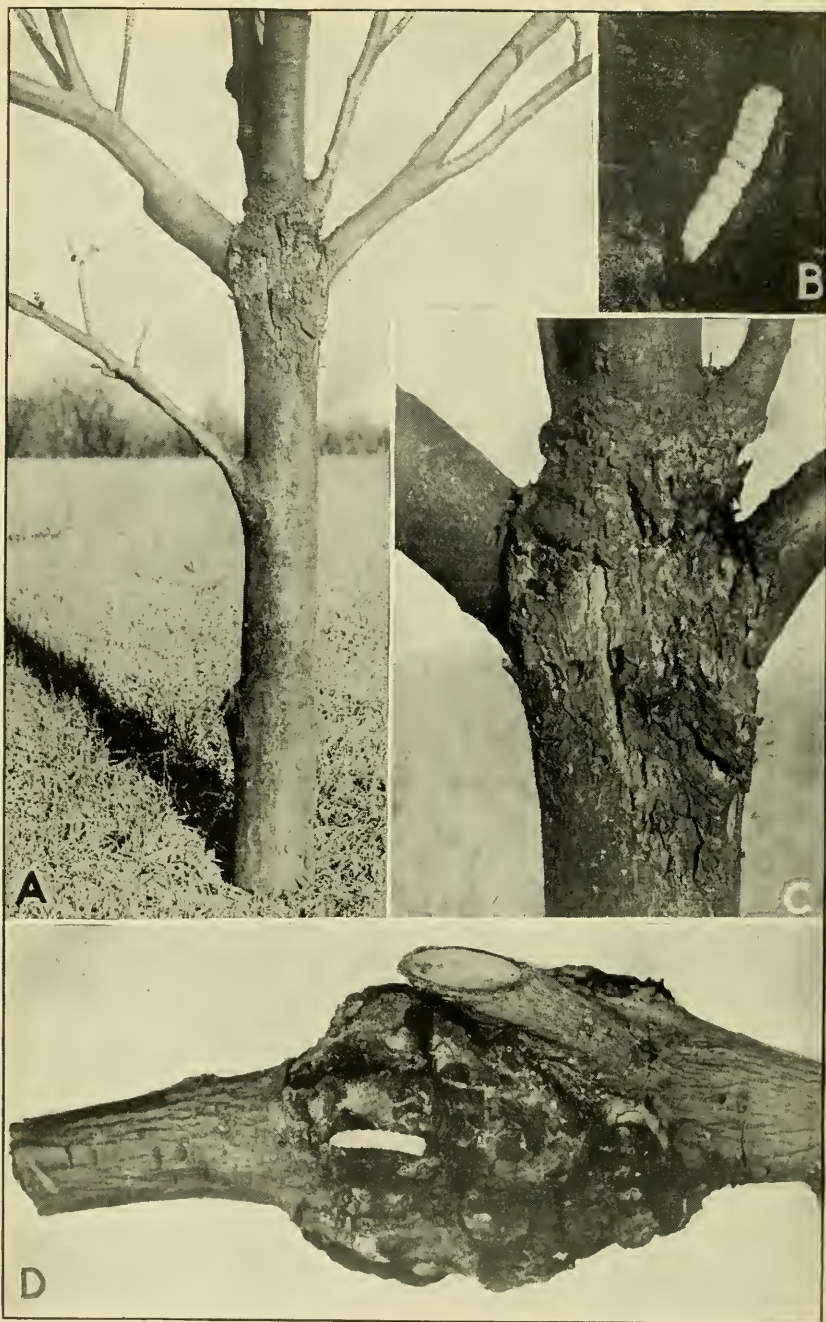
Larval activity begins early in the spring and is marked by the ejection of fresh, reddish castings through the bark and, often, by a few drops of brownish water oozing from the wounds. Active feeding has been observed in West Virginia as early as the last of March. The larva winters in a silk-lined hibernaculum constructed in that part of the burrow where the larva chances to be when overtaken by the cool weather of autumn. (Pl. I, G.) Some of the larvæ attain full growth in the fall, and, after wintering in their hibernacula, construct cocoons in the spring without further feeding. These cocoons are formed by reshaping and adding to the hibernacula.

In West Virginia there are both one-year and two-year larval periods, the duration of this stage of the insect's existence evidently depending somewhat upon food conditions but more upon the time in the season when the larva hatched. Apparently, larvæ from early-laid eggs usually transform to adults the following season, having thus a one-year life cycle, while those from late-laid eggs live in the tree as larvæ over two winters, having a two-year life cycle. On account of the difficulty of obtaining eggs, no individuals were reared under constant observation from eggs to adults. Over a hundred newly hatched larvæ, however, were collected at various times in the summer and planted in apple trees where their develop-



STAGES OF THE PEAR BORER.

A, Eggs in natural position; much enlarged. B, Larva, pupa, and cocoon; enlarged. C, D, Empty pupa cases projecting from the bark. E, Adult. F, Cocoons exposed by removing scales of apple bark; enlarged. G, Larva in hibernaculum; slightly enlarged.



PEAR BORER AND NATURE OF INJURY TO TREES.

A, Young apple tree showing characteristic injury at base of larger branches. *B*, Larva in burrow in apple bark; enlarged. *C*, Same as *A*, showing injury more in detail. *D*, Borer working in excrescence on apple branch; natural size.



TRUNK OF APPLE TREE, SHOWING SERIOUS INJURY BY PEAR BORER.

ment could be watched. Of these approximately 25 per cent had a one-year larval period and 75 per cent had a two-year larval period. It is possible that in the South, where the annual feeding season is longer, a one-year larval period may be the rule, while in the North, where the summers are shorter, there may be a constant two-year period for this stage.

THE PUPA.

Pupation takes place within an oblong-ovate cocoon formed of small particles of wood held together by a tough fiber of silk. The cocoon is always hidden beneath a scale of bark or wood fragments. (Pl. I, B, f.) The pupa (Pl. I, B), which is from 8 to 10 mm. in length, is at first yellowish white in color but soon changes to brown, the shade of color deepening as the imaginal stage is approached. The posterior margins of the abdominal segments are marked with rings of slightly darker brown. The segments beyond the sixth are armed each with two rings of saw-tooth-like points which slant backward, the points on the front ring of each segment being strongest and extending at the ends slightly beyond the spiracles. The points on segments beyond the eighth are stronger than those in front.

When the adult is ready to issue the pupa works forward until only the tip of the abdomen remains in the cocoon and the posterior end projects out through the bark. The pupa case then splits across the head just back of the antennæ, the rupture sometimes extending down the back of the thorax, and the moth issues suddenly and crawls away a short distance to harden. The empty pupa case is left projecting from the bark. (Pl. I, C, D.) In one case observed the pupal stage covered a period of 23 days. Table I indicates the time when cocoons are constructed in various localities and shows other vernal activities of the insect.

TABLE I.—*Spring activities of the pear borer.*

Year.	Month and day.	Locality.	Remarks.
1912	June 5	French Creek, W. Va..	Cocoons plentiful. Moths issuing.
1913	Apr. 18	Moorefield, W. Va.....	Cocoons found on old apple tree.
1915	June 21	French Creek, W. Va..	About half of individuals in cocoon.
1915	June 29	do.....	Of 60 individuals 4 had pupated.
1915	Apr. 25	Holly Springs, Miss..	A few larvæ have entered cocoons.
1915	Apr. 29	Gadsden, Ala.....	Several cocoons found on apple tree.
1915	May 4	Biltmore, N. C.....	No cocoons. Larvæ plentiful.
1916	May 12	French Creek, W. Va..	Less than half are in cocoons.
1916	June 16	Winthrop, Me.....	No cocoons. Larvæ plentiful.
1917	May 16	French Creek, W. Va..	Cocoons with larvæ in them.
1917	May 18	do.....	1 pupated May 18, adult June 11.
1918	May 6	do.....	Cocoons present on apple trees.
1918	May 8	do.....	About half the larvæ are in cocoons.

It may be seen from the foregoing table that at French Creek, W. Va., where most of the observations were made, the first cocoons were found on May 6 and the last on June 29.

THE ADULT.

The adult of the pear borer (Pl. I, E) is a dainty little moth having an expanse of from 12 to 17 mm. and a length of from 7 to 10 mm. The wings are transparent, veined, bordered, fringed, and tipped with metallic purplish black or brownish black, the dark areas being partially covered beneath with yellow scales. The upper parts of the body are purplish black with white and yellow markings on the head, yellow markings on the thorax, and three more or less distinct yellow bands around the abdomen. The legs and underparts are heavily marked with golden yellow, the antennæ and anal brush usually being marked with the same color. The colors throughout have a metallic luster, especially in fresh specimens. The scales rub off easily and there is considerable variation in color marks on this account, especially with specimens taken in the field.

Table II, based on field and laboratory notes, indicates the time of year when moths are found issuing in different localities.

TABLE II.—*Time of issuing of pear borer moths in different localities.*

Year.	Month and day.	Locality.	Remarks.
1911	Aug. 15	French Creek, W. Va.	One moth issued.
1911	Aug. 27	do.....	Do.
1912	June 4	do.....	First moth of season issued.
1913	May 13	Moorefield, W. Va.	Moth issued from cocoon found April 18.
1915	June 21	French Creek, W. Va.	First moth of season issued.
1915	Apr. 29	Gadsden, Ala.	Moths were issuing from cocoons on apple.
1915	Apr. 26	Love Station, Miss.	2 moths had issued from cocoons.
1916	May 19	French Creek, W. Va.	8 moths issued from May 19 to June 2.
1916	July 20	do.....	2 moths from material brought from Maine.
1916	July 22	do.....	Moth issued from cocoon from Michigan.
1917	June 11	do.....	Moth issued that had pupated 23 days before.
1918	May 11	do.....	First moth of season issued.
1918	June 1	do.....	Moths issuing in abundance.
1919	June 18	Quincy, Pa.	Many moths flying in apple orchard.

The foregoing table shows that the earliest record for moths is April 26, at Love Station, Miss. At French Creek, W. Va., where the rearing work was done, moths issued from May 11 to August 27, emergence covering a period of 108 days.

OVIPOSITION.

Many attempts were made to observe oviposition before the act was finally witnessed. Ovipositing females were first observed on June 18-19, 1919, in a large apple orchard at Quincy, Pa. The weather at the time was clear and warm and oviposition took place during the brighter part of the day, being most active from 10 a. m. to 4 p. m.

A series of badly infested trees were located and by visiting one tree after another a number of female moths were found hovering about the trunks and the bases of the larger branches. Their flight was rapid and wasplike but the light-colored markings of the ab-

domen and antennæ made the insects fairly conspicuous against the dark background of bark. The moths had to be approached warily, for they were quick to take alarm at any careless motions made in their near presence. When frightened they disappeared almost instantly and it was useless to try to follow them to another tree. In ovipositing the moths flew with a wavering, gliding movement near to the tree with the antennæ brushing the bark. They alighted at frequent intervals and moved the tip of the abdomen back and forth as they crawled over the bark seeking for a rough surface or a crack in which to place an egg. Sometimes the entire abdomen would be inserted under a scale of bark, or into an opening, where it would be held motionless for a second while the egg was being laid. Evidently a female lays only one egg in a place at a time, but repeated visits of females to a suitable location result in the eggs being grouped together by the end of the oviposition season. In one instance seven eggs were found in a heap at the bottom of a crack in the bark. The eggs are so small and inconspicuous that it is next to impossible to find them on the bark, even with an ordinary hand lens. Specimens of bark on which female moths had been seen to alight, but on which no eggs could be found in the field, were taken to the laboratory and placed under a microscope, where numerous eggs were easily discovered.

CANNIBALISTIC TENDENCIES.

In several instances a number of larvæ of different sizes were collected in the field and placed with pieces of live apple bark in large vials to be taken to the insectary. Sometimes the larvæ would be retained in the vials for several days. In all such cases it was found that the larger larvæ would kill and devour the smaller. That cannibalism is sometimes practiced under normal conditions is indicated by the fact that the larvæ are always found occupying burrows independent of one another, although eggs are frequently laid in groups. In a few cases small larvæ were found devouring their own kind on the trees.

NATURAL ENEMIES.

It is a common thing to find burrows of the pear borer that have been opened and the occupants removed by woodpeckers, although the species of bird responsible has not been observed. The larvæ and pupæ are rather extensively attacked by parasites, perhaps 50 per cent of them being destroyed in this way. Table III gives a list of the hymenopterous parasites reared by the writer from the pear borer. In addition to the species named in the table, there is a record of another parasite, *Stilbopoides sesiavora* Roh.,⁵ reared from this host.

⁵ ROHWER, S. A. DESCRIPTIONS OF NEW PARASITIC HYMENOPTERA. In Proc. Ent. Soc., v. 15, p. 189-188, 1913.

TABLE III.—*Hymenopterous parasites reared from the pear borer, Aegeria pyri Harris.*

Quaintance Series No.	Name.	Locality.	Year.	Determined by—
9402	<i>Microbracon</i> sp.....	Gadsden, Ala.....	1915	R. A. Cushman.
9407	<i>Phacogenes ater</i> Cress.....	Love Station, Miss.....	1915	S. A. Rohwer.
9429	<i>Lissonota</i> n. sp.....	French Creek, W. Va.....	1915	R. A. Cushman.
9431	<i>Itopectis annulipes</i> (Brullé).....	do.....	1915	Do.
9468	<i>Macrocentrus</i> n. sp.....	do.....	1917	S. A. Rohwer.
9499	<i>Ephialtes aequalis</i> (Prov.).....	do.....	1918	Do.
9531	<i>Tetrastichus</i> sp.....	do.....	1919	A. B. Gahan.
9539	<i>Ephialtes aequalis</i> (Prov.).....	Quincy, Pa.....	1919	R. A. Cushman.

METHODS OF CONTROL.

The borers of this species work so near the surface that they can usually be removed with a sharp knife without difficulty and without much injury to the tree. It is not always easy to locate their burrows, but as a rule exuding frass and often a spot of moisture on the bark show where the insects are working. The rough places on the bark where groups of borers feed continuously can be pared away with a knife, the borers removed, and then the surface covered with coal-tar creosote tree paint or white-lead paint. Such a coat of paint is not only beneficial in protecting the wounds from air and moisture, but to some degree it prevents reinfestation by the insects. In one case in a badly infested apple orchard, in the State of Mississippi, several applications of a heavy paint to the rough areas where the borers were congregated served almost entirely to rid the trees, for a few years at least, of these insects. It was found also that applications of viscous material, such as is used on sticky fly paper, made in the summer to these rough places, entangled many of the moths when they visited the places to lay their eggs.

The shallow burrows of this species make it possible to kill many of the borers by applications to the bark of penetrating oily or poisonous liquids. Kerosene emulsion and the standard emulsified oil sprays, with small quantities of sodium arsenate added, when applied to the bark over the burrows killed as high as 85 per cent of the borers. Nicotine sulphate washes were less effective, but some of the coal-tar products killed over 90 per cent of the borers without perceptible injury to the bark. The heavy oil materials, however, should always be used with caution until assurance is obtained of their non-injurious effects upon the trees.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 888

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief



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RESULTS OF EXPERIMENTS WITH MISCELLANEOUS SUBSTANCES AGAINST CHICKEN LICE AND THE DOG FLEA.

By W. S. ABBOTT, *Entomologist, Enforcement Insecticide Act.*

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INTRODUCTION.

In connection with the enforcement of the insecticide act of 1910 a large number of proprietary insecticides and the ingredients entering into their composition have been tested against chicken lice and the dog flea. These experiments have been briefly summarized and form the basis of this bulletin.

This work was done at the Insecticide Board's testing laboratory, located at Vienna, Va., which is under the supervision of Dr. A. L. Quaintance, of the Bureau of Entomology, and under the direct charge of Mr. E. W. Scott.¹

Assistance was also rendered at different times by Messrs. W. F. Turner, J. F. Zimmer, and W. B. Sill.

¹ Resigned July 15, 1919.

CHICKEN LICE.

Several species of lice were present on the fowls used in these tests, viz, the body louse, *Menopon biseriatum* Piaget; the shaft louse, *Menopon pallidum* Nitzsch; and the large hen louse, *Goniocotes abdominalis* Piaget. The most abundant species were the body louse and the shaft louse and these were always present in large numbers.

METHODS OF TESTING.

Three general methods of testing were employed: First, treating the individual fowls by dusting, spraying, dipping, or the "vent treatment" (see Mercurial ointment, p. 4-5); second, fumigation by confining the fowls in a box which had been painted or sprayed inside with the material to be tested; and, third, painting or spraying the roosts and dropping boards or the whole interior of the house.

Dusting.—Two persons worked together in dusting, one holding the bird and spreading the feathers, while the other applied the powder with a shaker or small hand dust gun. Except where noted the powders were well rubbed into the feathers.

Spraying.—The liquids were applied with a hand sprayer and were also well rubbed in, unless otherwise noted.

Dipping.—In the dipping tests the birds were held in the solution for from one-half to one minute and the head was submerged for about a second, once or twice.

Vent treatment.—In these tests the materials were thoroughly rubbed into the skin of the fowl around, or just below, the vent.

Fumigation.—In these tests the liquids, largely hydrocarbon oil mixtures, were applied to the bottom or bottom and sides of a box and the infested fowls were then placed in the box, which was covered with two or three thicknesses of burlap. The birds were left in the box for from 5 minutes to 3 hours.

Painting the house.—For these experiments the roosts and dropping boards, and often the whole interior of the chicken house, were painted or sprayed a short time before the birds went to roost, and the house remained tightly closed for that night.

OIL PREPARATIONS USED AS SPRAYS.

Tests with 22 different mixtures containing hydrocarbon oils, phenols, nitrobenzol, coal tar, wood-tar distillate, pyridine bases, and soaps showed that such preparations will kill practically all of the lice if lightly applied. The emulsions at dilutions not greater than 1 to 100 are also effective, but a dilution of 1 to 250 is of no value. Dipping tests indicated that these preparations are effective at about the same dilution. When dipped in or rubbed with the undiluted oils the fowls as well as the lice were killed. In two tests fowls dipped

in lime-sulphur concentrate (33° Baumé), diluted 1 part to 14 parts of water, were completely freed from lice.

The use of these mixtures can not be highly recommended for the following reasons: Too heavy an application may kill or seriously injure the treated birds; the plumage is left in a soiled and dirty condition and the oils retained on the feathers may have an injurious effect on the eggs in the case of sitting hens. Unless the dipping or spraying is done on a warm, clear day there is danger that the fowls may become chilled.

OIL PREPARATIONS USED AS FUMIGANTS.

Table I shows the results of tests with oil mixtures used as fumigants against chicken lice.

TABLE I.—*Results of tests with oil preparations used as fumigants against chicken lice. Two or more fowls confined in a sprayed or painted box for each test.*

Test No.	Active ingredients. ¹	Treatment.	Exposure.	Per cent killed.
			<i>Minutes.</i>	
1	Neutral coal-tar oil.....	Interior of box painted....	5	0
2	Coal-tar distillate, ammonia.....	do.....	10	100
3	Phenols, coal-tar hydrocarbon oils.....	Bottom of box painted....	10	0
4	Coal-tar oils, phenols.....	do.....	15	0
5	Coal-tar creosote oil.....	Interior of box painted....	30	100
6	Coal-tar distillate.....	do.....	30	100
			<i>Hours.</i>	
7	Phenols, light oil from coal tar.....	do.....	1	100
8	Neutral tar oils, phenols, pyridine.....	do.....	1	100
9	Creosote oil.....	do.....	1	100
10	Kerosene oil, pine oil.....	do.....	1	100
11	Coal-tar light oil.....	Bottom of box painted....	1	100
12	Coal-tar oils, phenols.....	do.....	1	100
13	Coal-tar oil, naphthalene, anthracene.....	do.....	1	75
14	Neutral coal-tar oil.....	Interior of box painted....	2	100
15	Coal-tar distillate.....	do.....	2	95-100
16	Creosote oil, mineral oil.....	do.....	2	95-100
17	Coal-tar distillate.....	do.....	2	98-100
18	Creosote oil, anthracene.....	do.....	2	100
19	Benzol, tar acids, naphthalene.....	do.....	2	100
20	Coal-tar oils.....	do.....	3	100
21	Coal-tar emulsion.....	do. ²	3	100

¹ An active ingredient is one that is effective against chicken lice when used at a proper dilution.

² Diluted 1 to 25.

This table shows that almost all of these preparations were very effective against lice when the fumigation was continued for not less than 30 minutes. If only the bottom of the box was treated, an exposure of 10 or 15 minutes failed to kill any lice but when the whole interior of the box was painted or sprayed a fumigation of 10 minutes was effective. An exposure of 5 minutes under the latter conditions was of no value.

Although effective, this method of treatment can not be recommended because of the injurious effect on the fowls. While no chickens were actually killed in these tests they were all more or less affected by the treatment as was shown by their very laborious

breathing and general weakness when released from the box. These effects passed away in 5 or 10 minutes, and in no case was any permanent injury noted. This treatment also left the feathers somewhat soiled, as the fowls in their struggles came in contact with the freshly treated surfaces of the box.

In two tests where the bottom of the nest box used by a sitting hen was painted with this type of preparation it was noted that from 95 to 100 per cent of the lice on the hen were killed or repelled and the eggs apparently were not injured. While sufficient tests were not made to determine the practicability of this treatment for the control of lice on sitting hens, it appears to be worthy of further investigation.

OIL PREPARATIONS APPLIED TO ROOSTS, DROPPING BOARDS, AND INTERIOR OF CHICKEN HOUSES.

There have been many advocates of the theory that chicken lice can be killed by painting the roosts and dropping boards or the whole interior of the poultry house with various oil mixtures, the idea being that the vapors or gases arising from these paints would penetrate the feathers of the roosting fowls and kill the lice. This method was given a very extensive trial and not one of the 42 different preparations tested was found to be of any value. These preparations contained one or more of the following ingredients: Phenols, tar oils, hydrocarbon oils, creosote oil, carbon disulphid, wood-tar distillate, benzol, nitrobenzene, naphthalene, anthracene oil, and pyridine and were of the same general character as those discussed in Table I (p. 3).

In these experiments the roosts and dropping boards or the whole interior of the house were thoroughly painted or sprayed just before the fowls went to roost and all doors, windows, and ventilators were closed during the first night. Five badly infested fowls were used in each test and at the end of one week examination was made for living lice. Although an occasional dead louse was found on the dropping boards, in no case was the treatment of any practical value. Since many of these same preparations were found to be effective when used as fumigants in small boxes, it is apparent that the ineffectiveness of this house treatment is due to the fact that the fumes do not become concentrated enough to kill the lice. Tests were also made with lime-sulphur applied in the same way and this also was found to be of no value.

MERCURIAL OINTMENT.

Five proprietary and two homemade mercurial ointments were tested and found to kill from 95 to 100 per cent of the body lice present. These ointments contained from 3 to 26 per cent of mercury mixed with lard, vaseline, paraffin, or some semisolid of this type

and were applied by rubbing a piece about the size of a pea well into the skin around or below the vent of the infested fowls. This method of treatment has been thoroughly tested by G. H. Lamson and J. A. Manter.² The active ingredient here is the mercury, since paraffin or vaseline applied in the same manner is of no value.

CHICKEN-LICE POWDERS.

Forty-five of the common proprietary powders generally sold as "Lice Powder," "Lice Killer," "Lice Exterminator," etc., were tested and, with a few exceptions, were found to be effective if thoroughly applied. These powders are all of the same general type and contain one or more of the following active ingredients: Naphthalene, nicotine, sulphur, pyrethrum, or phenols, and are mixed with lime, sand, talc, fuller's earth, or diatomaceous earth as a filler or carrier. Most of these active ingredients have been tested separately, and the minimum amounts that will be completely effective when very carefully and thoroughly applied by experienced persons are as follows: Naphthalene 10 per cent, nicotine 0.75 per cent, sulphur 20 per cent (?), pyrethrum 5 per cent, phenols 15 per cent (?).

In some of these powders the actual percentage of one or even all of the active ingredients fell below the minima given above, but the combined action of all of the active ingredients was sufficient to make the preparation effective.

MISCELLANEOUS PREPARATIONS.

In two tests, in which powders containing nicotine, naphthalene, and sulphur were added to the dust baths furnished to lousy hens, 95 to 100 per cent of the lice were killed. This method of treatment is not, however, a very practical one, since all fowls do not dust themselves and the few that do not will eventually reinfest the whole flock.

Nicotine, if used at a reasonable strength, was found to be effective as a dip or spray.

Lime-sulphur added to the drinking water (1 teaspoonful to a gallon), and a powder composed of sulphur, salt, sodium carbonate, naphthalene, charcoal, and lime, which was given with the food, were found to be absolutely without any effect on the lice.

PYRETHRUM POWDER.³

In a series of 12 tests pyrethrum powder (insect powder, Dalmatian insect powder, or Persian insect powder) was found to be very effective, killing all of the lice within 24 hours. In dilution tests it was found that a powder containing 5 per cent of pyrethrum was effective if very thoroughly and carefully applied.

² Lamson, G. H., jr., and Manter, J. A. Some lice and mites of the hen. Storrs Agr. Exp. Sta., Storrs, Conn., Bul. 86. 1916.

³ Powdered flower heads of *Pyrethrum cinerariaefolium* and *P. roseum*.

Powdered pyrethrum stems were carefully tested and proved to be of no value against these insects.

TOBACCO POWDERS.

A series of 27 tobacco powders ranging from 0.025 to 5.26 per cent nicotine was thoroughly tested against chicken lice and the results of these tests may be summarized briefly as follows: From 0.75 to 1 per cent of nicotine is of some value against these lice, but 1.15 or 1.25 per cent is as low as can be relied on for the best results, and even then the powder must be very freely and carefully applied.

NAPHTHALENE.

A large amount of work has been done with naphthalene in various forms as a remedy against chicken lice.⁴ The data gathered show that powders containing 20 per cent or more are very effective but can not be generally recommended, since as little naphthalene as 10 per cent may temporarily injure the dusted fowls and 60 per cent may kill them if the powder is well rubbed in.

Finely powdered naphthalene was found to kill from 20 to 100 per cent of the lice when sifted over the backs of fowls after they had gone to roost at night. While in no case were the lice completely eradicated by this treatment, and it is not as effective as the dusting of the individual birds, it is considered that this method may be of some value.

Numerous tests with naphthalene (6.49 to 100 per cent) nest eggs, which have been frequently sold as remedies for lice on laying and sitting hens, proved that they were of absolutely no value. When these eggs were placed in nests used by laying hens and allowed to remain from 1 to 3½ weeks, no effect could be noted on the lice and in several cases they were more abundant at the close of the experiment than at the beginning. They were useless against lice on sitting hens either when placed under the hen for two hours each week (as recommended), or when allowed to remain under the hen for the entire incubation period. Under the latter conditions, especially during hot weather, the hens were frequently driven from the nest and some of them were made very sick for two or three days. There was also considerable evidence to show that the eggs were seriously injured by the naphthalene, but not enough data are available to prove this absolutely.

MISCELLANEOUS POWDERED SUBSTANCES.

The following is a list of powdered substances that were found to be effective against chicken lice when used as dusts: Arsenic trioxid, barium fluorid, barium tetrasulphid,⁵ borax, boric acid, cloves, naph-

⁴ Abbott, W. S. Naphthalene v. Chicken lice. *In Jour. Econ. Ent.*, v. 12, no. 5, p. 397-402. 1919.

⁵ Did not kill all the lice.

thalene, paradichlorobenzene, sabadilla seeds, sassafras bark, sodium fluorid, flour of sulphur, and refined sulphur. Only a few of these materials can, however, be considered of any practical value in the control of chicken lice. Arsenic trioxid is too poisonous; barium fluorid, cloves, sabadilla seeds, and paradichlorobenzene are too expensive, or not readily available in large quantities; naphthalene is dangerous if applied too freely,⁶ and barium tetrasulphid does not kill all of the lice.⁶

Sodium fluorid, which was first tested in 1915 and found to be very effective, is the most practical remedy given in this list. This material has been tested on a practical scale by F. C. Bishopp and H. P. Wood⁷ and is recommended by them as the best insecticide for the control of this pest.

The materials listed below were found to be of no value against chicken lice:

Angelica root.	Hellebore.
Calcium carbonate.	Lime, air slaked.
Calcium fluorid.	Lime, water slaked.
Calcium hydroxid.	Magnesium carbonate.
Calcium oxid.	Magnesium oxid.
Calcium sulphate.	Magnesium silicate.
Colocynth pulp.	Orris root.
Diatomaceous earth.	Quassia chips.
Dolomitic lime.	Road dust.
Eucalyptus leaves.	Silica.
Ferrous oxid.	Sodium bicarbonate.
Flour, wheat.	Vermilion.
Gypsum.	Yellow ochre.

The fact that 26 different finely powdered materials—7 organic and 19 inorganic—were found to be of no value shows the fallacy of the old idea that any fine powder is effective against chicken lice if dusted into the feathers.

SUMMARY.

1. Oil mixtures were effective when lightly sprayed on the birds. When used as dips or when well rubbed into the feathers the treated fowls were killed. Oil emulsions were effective at a dilution not greater than 1 to 100.

2. Fumigation with oil preparations, the infested bird being placed in a sprayed or painted box for not less than 30 minutes, was effective. The fowls were somewhat injured by this treatment, but soon recovered.

3. Oil preparations were of no value against chicken lice when painted or sprayed on the roosts, dropping boards, and the whole interior of the chicken house.

⁶ See page 6.

⁷ Bishopp, F. C., and Wood, H. P. Mites and lice on poultry. U. S. Department of Agriculture Farmers' Bulletin 801. 1917.

4. Mercurial ointment, applied around or just below the vent of the fowl, was very effective, and vaseline and paraffin were of no value when applied in the same way.

5. Forty-five chicken-lice powders containing naphthalene, nicotine, pyrethrum, sulphur, and phenols proved to be effective when the active ingredients were present in the necessary amounts.

6. Powders containing nicotine, naphthalene, and sulphur were effective against chicken lice when added to the dust bath. Lime-sulphur added to the drinking water and one powder which was mixed with the food had no effect on the lice.

7. Pyrethrum powder was very effective, and pyrethrum stems of no value against chicken lice.

8. Tobacco powders containing not less than 0.75 to 1 per cent of nicotine are of some value but do not kill all of the lice. About 1.5 per cent is required for the best results.

9. A powder containing 10 per cent of naphthalene was effective against these pests but slightly injured the fowls, and 60 per cent killed the birds when well rubbed in. Naphthalene sprinkled over the backs of fowls at roost proved to be of considerable value against chicken lice. Naphthalene nest eggs were of no value against lice and proved injurious to sitting hens.

10. Thirteen miscellaneous powdered materials were tested and found to be effective and 26 ineffective against chicken lice.

RECOMMENDATIONS.

Since chicken lice breed on the body of the fowl, it is necessary to treat each and every bird in the flock for the control of these pests, and no treatment of the roost, dropping boards, or chicken house can be of any value.⁸

The following insecticides have been found to be very effective:

*Mercurial ointment.*⁹—This remedy is prepared by mixing 1 part of mercurial ointment (50 per cent metallic mercury) with 1 or 2 parts of vaseline, lard, or some other carrier of like consistency. A lump of this ointment about the size of a pea is rubbed into the skin just below or around the vent and an equal amount under each wing. A slight reddening of the skin may result, but no permanent injury has been noted.

*Sodium fluorid.*¹⁰—This material, used as a dust or as a dip at the rate of 1 ounce commercial or $\frac{3}{4}$ ounce chemically pure sodium fluorid to 1 gallon of water, has been found to be very effective.

Sulphur.—Used freely as a dust, sulphur forms a cheap and very effective lice killer.

⁸ This house treatment, on the other hand, is absolutely essential for the control of the chicken mite, *Dermanyssus gallinæ* Redi.

⁹ For a full account of experiments with this material see Lamson, G. H., and Manter, J. A., op. cit.

¹⁰ See Bishopp, F. C., and Wood, H. P., op. cit.

Pyrethrum.—Good, fresh pyrethrum powder is one of the best insecticides for the control of lice, but is too expensive for use on a large scale.

THE DOG FLEA.¹¹

METHODS OF TESTING.

The tests of insecticides against the dog flea were made under natural conditions except that the dogs were not allowed to return to the kennels until after the final records had been taken, as the kennels were, at all times, badly infested with fleas. Before each test the dogs were carefully examined to ascertain the degree of infestation and, unless a fairly large number of fleas was found, the animal was not used. After the dogs had been treated they were confined in large wire cages or tied to trees in the open air. Examinations were made at the end of 2, 24, or 48 hours, but no test was closed at the end of 2 hours unless nearly all of the fleas had been killed or repelled. It was considered that a material which had produced no noticeable results in 24 hours was ineffective. The sprays were applied with a hand sprayer, and the dusts with a small powder gun or a tin shaker. Both dusts and sprays were well rubbed in with the hand unless otherwise noted. In testing the washes, the dogs were placed in a tub containing 4 or 5 inches of the wash to be tested and thoroughly scrubbed by means of a sponge or cloth dipped in the liquid. In the dipping tests the animals were immersed for 1 or 2 minutes in the solution until all but the mouth and eyes were covered and the top of the head was well soaked by hand. In every case the materials to be tested were very thoroughly and carefully applied, so that these results represent their maximum value.

The results are given as "per cent killed or repelled," and these figures are, of course, only estimates. In most cases, even when an effective remedy was used, very few dead fleas were found on the dogs at the time of examination, although there is very little evidence that any material, with the possible exception of naphthalene, actually drove the fleas from the dogs without killing them.

PYRETHRUM POWDER.

Table II gives the results of tests with pyrethrum powder and powdered pyrethrum stems against the dog fleas.

This table shows that pyrethrum powder (insect powder, Dalmatian powder, or Persian insect powder) is very effective but that powdered pyrethrum stems are of no value against the dog flea. It also shows that while 4 or 10 per cent of good pyrethrum is of value, at least 50 per cent should be used in a mixed powder to secure the best results.

¹¹ *Ctenocephalus canis* Curt.

TABLE II.—*Results of dusting tests with pyrethrum powders and powdered stems against the dog flea.*

Test No.	Active ingredients.		Inert ingredients.	Number of dogs treated.	Per cent of fleas killed or repelled.
	Per cent pyrethrum.	Miscellaneous.			
1.....	4.00	.....	Sulphur.....	2	50-80
2.....	10.00	.....	Sodium flourid and sand..	1	98
3.....	12.59	Naphthalene, 0.17 per cent	Sand and clay.....	1	30
4.....	18.00	.....	Filler(?).....	2	75-85
5.....	32.63	.....	Borax and talc.....	2	15-20
6.....	(?) 41.00	Cloves.....	Borax.....	2	100
7.....	(?) 88.00	.....	Hellebore.....	2	100
8.....	93.66	.....	Charcoal.....	2	100
9.....	100.00	.....	.....	1	100
10.....	100.00	.....	.....	2	100
11.....	100.00	.....	.....	1	100
12.....	100.00	.....	.....	1	100
13.....	.....	.....	Stems, 100 per cent.....	2	0
14.....	.....	.....	do.....	1	0
15.....	.....	.....	do.....	8	0

The low killing noted in tests Nos. 3 and 5 can be accounted for on the supposition that the pyrethrum in these mixtures had deteriorated since it has been shown¹² that pyrethrum, exposed to the air, loses practically all of its value in 150 weeks and when kept in sealed glass containers is worthless after 5½ years.

NAPHTHALENE.

Table III shows the results of dusting tests with various percentages of naphthalene against the dog flea.

TABLE III.—*Results of dusting tests with naphthalene against the dog flea.*

Test No.	Per cent naphthalene.	Inert ingredients.	Number of dogs treated.	Per cent of fleas killed or repelled.	Remarks.
1.....	1.52	Lime.....	2	0	Rubbed in.
2.....	6.48	Sulphur and lime.....	2	0	Do.
3.....	10.00	Flour.....	1	0	Not rubbed in.
4.....	12.17	Sand and lime.....	1	10-20	Rubbed in.
5.....	20.00	Flour.....	2	0	Not rubbed in.
6.....	40.00	do.....	1	0	Do.
7.....	50.00	do.....	1	0	Do.
8.....	59.21	Charcoal.....	2	50-60	Rubbed in.
9.....	75.00	Flour.....	2	5-10	Not rubbed in.
10.....	100.00	do.....	3	50	Do.
11.....	100.00	do.....	2	98-100	Rubbed in.

Table III shows that naphthalene, which frequently has been recommended against dog fleas, is effective, providing it is thoroughly rubbed into the hair and that powders containing 75 per cent or less are of little or no value. The table also shows very clearly the necessity of working the powder well down into the hair, since a powder containing 59 per cent (test 8) which was well rubbed in was as effective as pure naphthalene (test 10) which was only dusted over

¹² Abbott, W. S. A study of the effect of storage, heat, and moisture on pyrethrum. U.S. Department of Agriculture Bulletin 771. 1919.

the dogs. In order to be of any value this material must be finely pulverized, since, in the form that it is usually found on the market (moth balls or rather coarse flakes and crystals), it can not be well worked down to the skin, especially in the case of long-haired dogs. This material seems to act somewhat as a repellent, causing the fleas to drop from the animal in a partially stupefied condition.

CHICKEN-LICE POWDERS.

A large number of the so-called chicken-lice powders containing various amounts of naphthalene, tobacco powder, sulphur and lime, and occasionally small amounts of pyrethrum and phenols, were tested and found to be more or less effective against the dog flea, depending on the amounts of the active ingredients (naphthalene, nicotine, pyrethrum, and phenols) present and the fineness of the powders. Only 4 of the 21 powders of this type tested were found to be completely effective, although 10 of them killed from 75 to 95 per cent of the fleas.

MISCELLANEOUS POWDERED MIXTURES.

Five miscellaneous powders containing oils as the only active ingredient were tested and it was found that 18 per cent of sassafras oil was completely effective and that 10 per cent or less of several other oils was of no value. One powder composed of sawdust impregnated with 33 per cent of wood-tar creosote was of no value, this being due to the fact that the sawdust was so coarse that it did not penetrate to the skin.

MISCELLANEOUS POWDERED MATERIALS.

The following powdered materials were found to be more or less effective when used as dusts against the dog flea: Powdered cloves, naphthalene, paradichlorobenzene, and powdered sassafras bark. The results of experiments with them are given in Table IV.

TABLE IV.—*Results of dusting tests with various powdered materials against the dog flea.*

Name.	Number of dogs used.	Per cent of fleas killed or repelled.
Powdered cloves.....	4	100
Naphthalene.....	4	98-100
Paradichlorobenzene.....	2	100
Powdered sassafras bark.....	3	80-90

The miscellaneous powdered materials tested and found to be of no value against the dog flea were allspice, angelica root, borax, boric acid, calcium sulphate, calcium fluorid, cornstarch, colocynth pulp, diatomaceous earth, eucalyptus leaves, hellebore, air-slaked lime,

orris root, red pepper, quassia chips, road dust, sodium fluorid, sodium sulphite, flour of sulphur, refined sulphur, and sublimed sulphur.

It is of interest to note that sodium fluorid was found to be of no value against fleas, although it is very effective against chicken lice, it being considered by Bishopp and Wood ¹³ as the best remedy for this pest.

Sulphur, which has often been recommended against fleas, was found in nine tests to be of no value.

TOBACCO POWDERS.

A series of nine tobacco powders containing from 0.11 to 4.56 per cent of nicotine was tested. The powders containing 1 per cent or more of nicotine were somewhat effective, but even the highest percentage used did not kill all of the fleas. Since the tobacco powders sold on the market as insecticides rarely contain as much as 1 per cent of nicotine it can be readily seen that they can not be relied on for the control of this pest.

SPRAYS.

Table V gives the results of tests with emulsified disinfectants used as sprays against the dog flea.

TABLE V.—*Results of tests with emulsified disinfectants used as sprays against the dog flea.*

Test No.	Phenols.	Soap.	Other active ingredients. ¹	Inert ingredients.	Dilution.	Number of dogs used.	Fleas killed or repelled.
	<i>Per cent.</i>	<i>Per ct.</i>		<i>Per cent water.</i>			<i>Per cent.</i>
1.....	5.20	(?)	Creosote and mineral oil.....	(?)	None.	2	100
2.....	50.21	27.10	.....	(?)	1- 50	1	100
3.....	10.00	(?)	Neutral coal-tar oils.....	(?)	1- 64	1	100
4.....	17.20	23.40	Neutral coal-tar oils, 53.1 per cent..	6.3	1- 64	1	95
5.....	16.89	22.40	Neutral coal-tar oils, 52.4 per cent..	8.4	1- 75	2	0
6 ².....			.....	6.6	1- 75	2	0
7.....	16.80	22.40	Neutral coal-tar oils, 52.4 per cent..	8.4	1-100	2	0
8.....	10.80	20.40	Neutral coal-tar oils, 61.3 per cent..	7.5	1-128	1	0
9.....	10.80	20.19	Neutral coal-tar oils, 61.7 per cent..	7.5	1-130	2	0
10.....	54.00	20.00	.....	26.1	1-200	1	0
11 ².....			.....	7.4	1-250	2	0
12.....	12.30	32.40	Neutral coal-tar oils, 48.9 per cent..	8.4	1-260	2	0
13.....	10.80	20.10	Neutral coal-tar oils, 61.7 per cent..	7.5	1-260	2	0
14.....	30.40	(?)	Neutral coal-tar oils, 65.5 per cent..	4.1	1-264	1	0

¹ An active ingredient is a material effective against dog fleas when used at a proper dilution.

² An emulsified coal-tar disinfectant.

This table shows that as a class the emulsified disinfectants are effective against fleas when used as sprays at a dilution not greater than 1 to 64 (1 tablespoonful to a quart). This method of controlling fleas, however, is not a very satisfactory one since it is difficult to spray a dog properly and, in the case of dogs with long, thick hair, it is not easy to force the spray through it.

¹³ Mites and Lice on Poultry, Farmers' Bulletin 801, U. S. Department of Agriculture.

WASHES.

Table VI gives the results of tests with emulsified disinfectants used as washes against the dog flea.

TABLE VI.—*Results of tests with sprays used as fumigants against the dog flea.*

Test No.	Phenols.	Other ingredients.	Method of treatment.	Number of dogs.	Duration of test.	Killed or repelled.
	<i>Per cent.</i>				<i>Hours.</i>	<i>Per cent.</i>
1.....	16.16	Coal-tar creosote oil.....	Confined in painted box...	1	1	100
2.....	7.32	Coal-tar distillate.....	Confined in sprayed box...	2	$\frac{1}{2}$	100
3.....	5.00	do.....	Wrapped in sprayed blanket.	2	2	100
4.....	4.15	Benzol, naphthalene, tar acids, pyridine.	do.....	1	.....	100
5.....	2.17	Light coal-tar oil.....	do.....	1	2	100

These emulsified disinfectants proved to be very effective when used as washes at a dilution not to exceed 1 to 130 (2 tablespoonfuls to a gallon). Where dogs are regularly washed, as they should be, this method of treatment offers an easy and effective means for the control of fleas, since the emulsified coal-tar disinfectants are obtainable at almost any drug store and can very readily be added to the bath water.

DIPS.

Eight dipping tests were made with emulsified coal-tar disinfectants and, as might be expected, they were found to be effective at about the same strength as when used as washes, i. e., 1 part to 130 parts of water. At the rate of 1 to 200 in two tests only 20 per cent of the fleas were killed or repelled.

LIQUIDS USED AS FUMIGANTS.

Table VII gives the results of tests with liquids used as fumigants:

TABLE VII.—*Results of tests with sprays used as fumigants against the dog flea.*

Test No.	Phenols.	Other ingredients.	Method of treatment.	Number of dogs.	Duration of test.	Killed or repelled.
	<i>Per cent.</i>				<i>Hours.</i>	<i>Per cent.</i>
1.....	16.16	Coal-tar creosote.....	Confined in painted box.	1	1	100
2.....	7.32	Coal-tar oils.....	Confined in sprayed box.	2	$\frac{1}{2}$	100
3.....	5.00	Creosote oils and carbon disulphid.	Wrapped in sprayed blanket.	2	2	100
4.....	4.15	Benzol, naphthalene, nicotine, water.	do.....	1	.....	100
5.....	2.17	Light coal-tar oil.....	do.....	1	2	100

In tests Nos. 1 and 2 the interior of a box about 3 feet long, 2 feet wide, and 2 feet deep was thoroughly painted or sprayed, and a small dog was placed in the box, which was then covered with two or three thicknesses of burlap. This method of treatment produced a true fumigation, since the dogs in every case remained standing during the entire experiment. When the dogs were taken from the boxes examination showed no living fleas on them, and it is evident that the insects had been killed by the vapors arising from the sprays used. This view is supported by the results of a long series of tests of a similar nature, in which various oil preparations were found to be effective against chicken lice. (See p. 3-4.)

In tests Nos. 3, 4, and 5 the materials were lightly sprayed on a blanket or old sack, and this was tightly wrapped about the dog so that only the face and legs remained uncovered. This method of application gave, in addition to the fumigation effect, a very probable contact effect, since some of the oils would naturally pass from the blanket to the hair of the dog, and any fleas coming to the surface of the hair would come in contact with the sprayed blanket. This treatment was also very effective, as no living fleas were found on dogs that had been covered with the sprayed blankets for two hours.

SUMMARY.

1. Pyrethrum powder alone or when it formed not less than 50 per cent of a mixed powder was very effective, but pyrethrum stems were of no value.

2. Pure naphthalene was found to be effective if well rubbed into the hair.

3. Twenty-one lice powders were more or less effective, depending on the amount of active ingredients present and the fineness of the powder.

4. A powder containing 18 per cent of sassafras oil was effective, and powders containing 10 per cent or less of other oils were of no value.

5. Cloves, naphthalene, paradichlorobenzene, and sassafras bark were effective against fleas and 21 powdered substances were of no value.

6. Tobacco powders containing over 1 per cent of nicotine were of some value against fleas, but a powder containing as high as 4.56 per cent was not completely effective.

7. The emulsified disinfectants were found to be effective as sprays at the rate of 1 part to 64 parts of water and as washes and dips at 1 to 130.

8. Several liquids used as fumigants were found to be effective against fleas.

RECOMMENDATIONS.

A thorough dusting with good fresh pyrethrum powder is a simple and effective remedy against dog fleas. The powder can be easily applied by means of a hand dust gun, an old sugar shaker, or simply a tin can with small holes punched in the cover. It should be freely dusted over all parts of the body and well rubbed into the hair. If the dog is dusted in a shallow box or on an old blanket or a sheet of paper, the fleas, which will drop off in a stupefied condition, can be collected and burned.

Finely powdered naphthalene or paradichlorobenzene will be found effective if thoroughly rubbed into the hair and can be applied in the same manner as pyrethrum.

Where dogs are given regular baths, the addition of some of the common emulsified coal-tar creosote preparations generally sold as "emulsified coal-tar disinfectants," "coal-tar creosote dips," or "stock dips," or some emulsion containing cresols, phenols, or hydrocarbon oils, to the water at the rate of 1 to 130 (2 tablespoonfuls to the gallon) will be found very effective.

In considering the control of fleas it should be remembered that destroying those on the dog affords only a temporary relief, unless all breeding places are eliminated at the same time.¹⁴

If the dogs themselves are carefully dusted or washed and their kennels and sleeping places properly treated the flea problem will be solved.

¹⁴A full discussion of methods for the control of flea breeding will be found in Farmers' Bulletin 897, U. S. Department of Agriculture, "Fleas and Their Control," by F. C. Bishopp.



UNITED STATES DEPARTMENT OF AGRICULTURE

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L. O. HOWARD, Chief



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PROFESSIONAL PAPER

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CLOVER STEM-BORER AS AN ALFALFA PEST.

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INTRODUCTION.

The clover stem-borer (fig. 1) (*Languria mozardi* Latr.) has been known for a great many years, and is often briefly referred to in literature as a pest of red and mammoth clovers. In 1909 Prof. J. W. Folsom (16)¹ recorded many important facts regarding its life history and habits as an enemy of clover. The larvæ or young subsist upon the pith eaten from the center of the clover stems.

During recent years, especially in the southwestern semiarid and irrigated regions, the beetle has been discovered feeding upon alfalfa (*Medicago sativa*) and has become a pest of considerable importance to alfalfa culture. The young borer, as in the case of clover injury, eats the center of an alfalfa stem and causes it to become woody and possibly to break off and lodge.

The present paper is a complete account of the life history and habits of the insect as an enemy to alfalfa culture as well as a discussion of methods of controlling the pest.

EARLY HISTORY.

The clover stem-borer is distinctly a native of America, not being listed in European catalogues. The earliest record of it is in 1807,

¹ Figures in parenthesis refer to "Literature cited," p. 24.

by Latreille (1, p. 66), who described it and named it after Mozardi from specimens received from the United States. In 1828, Say (2) redescribed it and published the first figure of the adult beetle. It is mentioned by Lamarck (3, p. 486) in 1835, and nearly a half century after its first description it was listed by Melsheimer (4, p. 47) in his catalogue of the Coleoptera of the United States, while Leconte (5) mentions it a year later than this as occurring in the "Middle, Southern, and Western States." Motschulsky (6, p. 241) in 1867 reports it from North America, principally in Louisiana, and mentions it as common on cruciferous plants, and in 1873 Crotch (7) redescribes the species in detail and gives its habitat as Washington, Pennsylvania, Kansas, Nebraska, and the Southern States.

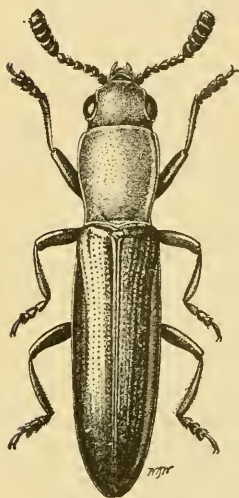


FIG. 1.—Adult of the clover stem-borer (*Tanguria mozardi*).

It is noticeable that in all these records no mention is made of the habits of the insect either in the young or adult stages, although for a good many years previous to 1879 the beetle had been frequently taken by collectors. It remained for Prof. J. H. Comstock (8, p. 199) in 1879 to discover that the larva of this beetle lives as a borer within the stems of red clover, and in the Report of the Entomologist for that year he records some of the discovered larval and adult habits. This short report stimulated further study, and in 1881 Lintner (9) gave the known history of this insect a prominent place in his excellent paper on "The insects of the clover plant." In 1886 Webster (10) noted what was doubtless the larva of this species feeding in timothy. In 1890 Chittenden (12) reported several plants of the Compositae as being hosts of this insect, while the same year Weed (13) published a summary of the known food plants and added a few new life-history notes. In 1894 Davis (14, p. 167) gave a brief account of this insect, and in 1907 Girault (15) made some interesting notes on the act of oviposition. The most recent and complete report was published by Prof. J. W. Folsom (16) in 1909. In all these published records the insect has always been treated as an enemy of clover, no mention having been made of it as a depredator on alfalfa.

DISTRIBUTION.

At the present time the clover stem-borer is known to inhabit practically all of the United States, as well as parts of Canada and northern Mexico. In 1909, Folsom (16) stated: "It inhabits the Middle

and the Southern States, some of the Western States, and parts of Canada." Members of the force of the Bureau of Entomology have collected it at the following places:

T. H. Parks:	G. G. Ainslie: Hurricane Mills, Tenn.
Asheville, N. C.	W. H. Larrimer: Nashville, Tenn.
Arlington, Va.	F. M. Webster: Lafayette, Ind.
Chevy Chase, Md.	V. A. Roberts: Oxford, Ind.
Wellington, Kans.	E. O. G. Kelley:
E. H. Gibson:	Dow, Ill.
Nashville, Tenn.	Coulterville, Ill.
Buena Vista, Tenn.	P. Hayhurst: Wellington, Kans.
A. B. Gahan:	J. A. Hyslop: Wolfville, Md.
Jackson, Tenn.	C. N. Ainslie: Wolsey, S. Dak.
Chattanooga, Tenn.	
W. E. Pennington:	
Meyersville, Md.	
Hagerstown, Md.	

The authors have taken it, in various localities, in Lower California, Mexico, and in California, Arizona, New Mexico, and Texas.

It is not only of wide distribution but it inhabits localities of widely different altitudes, occurring in the Imperial Valley of California, 250 feet below sea level, and at Ash Fork, Ariz., at an elevation of 5,148 feet. It is especially abundant, however, in the eastern and central red clover districts and reaches its greatest numbers in the southern and southwestern alfalfa districts.

FOOD PLANTS.

The two cultivated plants that seem to be the favorite food for the larva of this beetle are alfalfa and red clover. Besides these, the insect has a great variety of host plants, many of which belong to the Compositae. Fortunately many of these plants are weeds, the destruction of which will aid in the control of the depredator. A complete list of food plants with authority for each is given below:

Alfalfa (<i>Medicago sativa</i>).....	V. L. Wildermuth.
Red clover (<i>Trifolium pratense</i>).....	J. H. Comstock.
White sweet clover (<i>Melilotus alba</i>).....	C. M. Weed.
Yellow sweet clover (<i>Melilotus officinalis</i>).....	F. H. Gates.
Bur clover (<i>Medicago hispida</i>).....	V. L. Wildermuth.
Timothy (<i>Phleum pratense</i>).....	F. M. Webster.
Sunflower (<i>Helianthus annuus</i>).....	Gates and Wildermuth.
Ox-eye daisy (<i>Chrysanthemum leucanthemum</i>)....	} F. H. Chittenden.
Daisy fleabane (<i>Erigeron ramosus</i>)	
Prick fleabane (<i>Erigeron philadelphicus</i>)	} C. M. Weed.
Mares tails (<i>Erigeron canadensis</i>).....	
Thistle (<i>Cnicus altissimus</i>)	
Trumpet weed (<i>Lactuca canadensis</i>).....	
Wild lettuce (<i>Lactuca floridana</i>).....	
Cone-flower (<i>Rudbeckia laciniata</i>).....	
Yarrow (<i>Achillea millefolium</i>)	
Tall nettle (<i>Urtica gracilis</i>)	

Stinging nettle (<i>Urtica dioica</i>)	F. H. Chittenden.
Tall bellflower (<i>Campanula americana</i>)	C. M. Weed.
Horse-weed (<i>Ambrosia trifida</i>)	F. H. Chittenden.
Ragweed (<i>Ambrosia artemisiifolia</i>)	C. M. Weed.
Daisy (<i>Leucanthemum</i> sp.)	A. A. Girault.
Wheat grass (<i>Agropyron</i> sp.)	} C. N. Ainslie.
Marsh grass (<i>Spartina michauxiana</i>)	
Burdock (<i>Arctium minus</i>)	H. L. Parker.
Malva (<i>Malva rotundifolia</i>)	F. H. Gates.
Marsh grass (<i>Spartina cynosuroides</i>)	P. Hayhurst.

ECONOMIC IMPORTANCE OF THE INSECT TO ALFALFA AND CLOVER.

A great many farmers in the alfalfa-growing sections of the country, especially those of the Southern and Southwestern States, do not appreciate to how great an extent this borer is responsible, at certain times, for the poor, woody quality of their alfalfa hay. Nor do farmers in the eastern section of the country appreciate the small but nevertheless direct damage this borer exerts upon the productiveness of red and mammoth clovers.

It is not at all surprising that this condition exists, for the borer is hidden from view at all times, traveling up and down the center of an alfalfa stalk where the adult deposited the egg, and devouring the entire center of the stem, leaving a woody fibrous stalk that is deficient in foliage and high in crude fiber content. An infested stalk of alfalfa, during the heat of the day, will often show wilting from lack of a proper amount of water reaching the plant. This, of course, checks plant growth, and the wilting will usually cause the lateral leaves to fall; hence, an infested plant will have lost a large amount of its foliage.

In 1909, Folsom (16) said: "Were this insect more numerous it might gradually develop into a pest of considerable importance." In the southwestern United States, where it is widely distributed, the extent of the damage may be realized when we know that as high as 85 per cent of the stalks in an alfalfa field often are infested with this borer. This means that 85 per cent of the hay crop in that field will have stalks of a woody nature. It also means that a certain percentage of these stalks will have broken off and fallen and probably entirely lost their foliage. The result is a hay crop lacking leaves, high in crude fiber, and of a grade altogether inferior to that which might have been produced had this insect not been present.

Regarding the effect of the feeding of the larva on a clover stem, Comstock (8, p. 199) says:

While they do not kill the stem outright, they gradually weaken it and eventually cause its destruction, having also, of course, a very injurious effect upon the maturing of the seed.

Folsom (16), in his discussion of the effect upon clover, states:

The chief effect of the stem borer is, however, a mechanical one. The stems that are hollowed out fall to the ground prematurely, though not until they have attained a considerable size. One can find the borers most abundantly in the large prostrate stems rather than in the stems that remain erect. The plants that lodge carry their flowers to the ground, become soiled with dirt, and are not easy to mow.

Thus it is obvious that practically the same condition exists in the red-clover regions as in the alfalfa regions of the Southwest, only in the case of red clover the insect has never reached the excessive numbers that occur in the extensive alfalfa regions of the Southwest. This is doubtless due to the fact that only one generation annually is found in the former section of the country, while in the latter there are always three generations each year. When it is realized that this borer inhabits the whole of the United States, it can readily be seen that the annual toll taken by it from the farmers of this country runs into high figures.

DESCRIPTION.

THE ADULT.

The beetle (fig. 1) is slender and has a shiny appearance. The head and thorax are a deep red, while the remainder of the insect is a bluish-black. The surface of the elytra is indented by regular rows of punctures. The species was originally named and briefly described by Latreille (1), but considerably later redescribed in detail by Crotch (7, p. 350), whose description is as follows:



FIG. 2.—Eggs of the clover stem-borer.

Elongate, parallel, red, antennæ (except the base) and apical half of the femora black, tibiæ and tarsi brown, elytra bluish-green; head and thorax sparingly punctate, the latter elongate, the sides rounded in front, basal striae short; scutellum red; elytra punctate striate, interstices impunctate; underside sparingly punctate, 2-3 last ventral segment black. L. .22-.31 inch.

THE EGG.

The egg (fig. 2) is a very small, light cream-yellow, bean-shaped object from 1.5 mm. to 2 mm. long and about 0.5 mm. in diameter. Folsom (16) described it as:

Translucent cream-yellow, paler at each end, elliptico-cylindrical and slightly curving, with one end slightly more tapering than the other.

The eggs that the authors have observed vary greatly in color, newly laid eggs being almost white or colorless, while fully incubated eggs are a deep chrome-lemon color.

THE LARVA.

The larva (fig. 3) is exceptionally slender and is pale yellow in color. The very small and inconspicuous, although well-developed, feet, together with the quick wriggling movement of the larva in its burrow, give it much the appearance of a worm.

Comstock (8, p. 200) as early as 1879 gave a complete description of a full-grown larva, which is as follows:

Length 8^{mm}; color light yellow; tips of mandibles and anal horn brown. Subcylindrical in shape, the anal segment only being narrower than the preceding joint. Average width .9^{mm}. Thoracic legs long and stout; only one prop leg, which is under the anal segment. The anal segment is armed upon its dorso-posterior border with two upward-curved acute hooks placed close together. The head is broad, somewhat flattened dorso-ventrally. Antennæ prominent, 4-jointed, 3d joint longest, 4th joint slender. Labrum broad, rounded, with a row of small piliferous tubercles at its anterior border. Mandibles, 3 toothed. Maxillary palpi, 3 jointed. Labrum rounded anteriorly; labial palpi 2 jointed, stout.

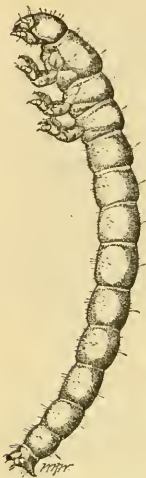


FIG. 3.—Full-grown larva of the clover stem-borer.

THE PUPA.

The pupa (fig. 4) is yellow, slender, and semicylindrical. The abdomen is darker in color than the rest of the body. The head is broader than either the thorax or abdomen, and the wing pads are prominent. The abdominal segments have short spines dorsally, by the aid of which the insect moves up and down the stem.

LIFE HISTORY AND HABITS.

THE LIFE CYCLE.

The average time required for this beetle to pass its complete life cycle is about 60 days. This period is noticeably shorter during the first generation than during later generations. This is due to the fact that during this generation the time elapsing from the issuance of the adult to copulation and oviposition is considerably shorter than in the subsequent generations. The apparent cause for this is that later in the year the beetles tend to cease their activities for the season rather than to continue a third and sometimes a partial fourth generation. The life cycle is shorter during the first generation in spite of the fact that the egg stage is considerably longer than during the months of July and August. (See rearing cage, fig. 5.)

The minimum life cycle has been noted to be as low as 50 days, while the maximum has often extended through a period of 65 to 70 days. The total length of the egg, larval, and pupal periods was found to average 49.1 days, with a minimum of 45 days and a maximum of 58 days. Table I shows the combined length of egg, larval, and pupal periods of 20 specimens carried through, by the junior author, from egg to adult, but does not show the period existing between issuance of adult and oviposition.



FIG. 4.—Pupa of the clover stem-borer.

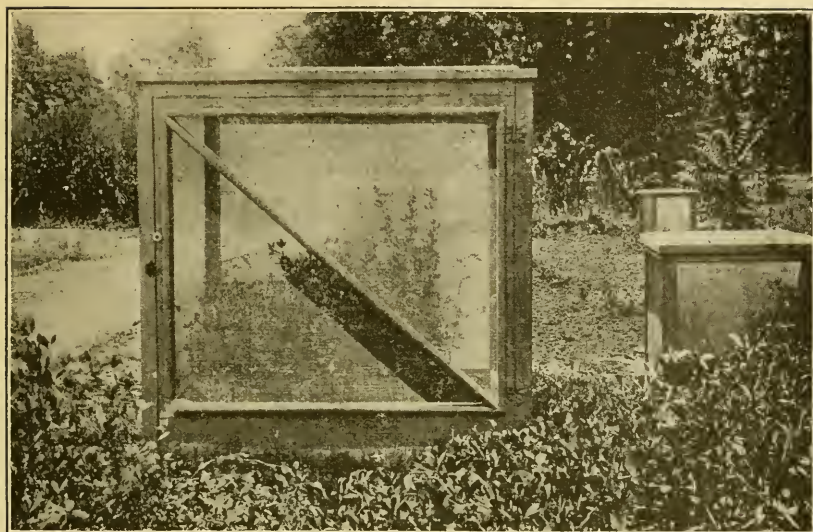


FIG. 5.—Type of cage used in generation records of the clover stem-borer on alfalfa.

TABLE I.—Duration of life cycle of the clover stem-borer in alfalfa at Tempe, Ariz.

[Observer, Gates.]

Cage No.	Eggs.				Date of pupation.	Length of larval stage.	Date adult issued.	Length of pupal stage.	Total length of life cycle.	Average mean temperature.
	Date laid.	Date hatched.	Number.	Length of stage.						
	1915.	1915.*		Days.	1915.	Days.	1915.	Days.	Days.	° F.
T 100-1.....	Apr. 2	Apr. 5	1	3	May 15	40	May 24	9	52	66
T 100-2.....	do.	do.	1	3	do.	40	May 29	14	57	66
T 100-3.....	do.	Apr. 6	1	4	May 17	41	May 25	8	53	65
T 104.....	Mar. 29	Apr. 1	1	4	May 12	41	May 19	7	52	60
T 104-1.....	Mar. 30	Apr. 4	1	4	May 15	41	May 24	9	54	65
T 104-2.....	Apr. 7	Apr. 10	1	3	May 17	37	May 25	8	48	60
T 104-3.....	Apr. 9	Apr. 12	1	3	May 15	33	do.	10.	46	60
T 104-4.....	do.	do.	1	3	May 17	35	May 28	11	58	65
T 115.....	do.	do.	1	3	May 25	43	June 2	8	54	66
T 492.....	Aug. 18	Aug. 21	1	3	Sept. 17	37	Sept. 25	8	48	70
T 784.....	Sept. 3	Sept. 7	1	4	Oct. 8	31	Oct. 18	10	45	76
T 791.....	Sept. 5	Sept. 9	1	4	Oct. 10	31	Oct. 22	12	47	75
T 791-2.....	do.	do.	1	4	do.	31	Oct. 23	13	48	75
T 791-3.....	do.	do.	1	4	Oct. 11	32	Oct. 25	14	50	75
T 795.....	Sept. 6	Sept. 11	1	5	Oct. 10	30	Oct. 20	10	45	73
T 876.....	do.	do.	1	5	Oct. 12	32	Oct. 24	12	49	73
	1916.	1916.			1916.		1916.			
T 1398-2.....	Mar. 12	Mar. 18	3	6	Apr. 20	34	Apr. 26	6	46	64
T 1405-2.....	Mar. 20	Mar. 25	1	5	Apr. 24	32	May 3	9	46	72
Total or average.....			20	4.1		35.5		9.5	49.1	.....

TABLE II.—Length of egg stage of the clover stem-borer (*Languria mozdari*) in alfalfa at Tempe, Ariz.

Cage No.	Observer.	Eggs.				Length of stage.	Average mean temperature.
		Date laid.	Num-ber.	Date hatched.	Num-ber.		
1.....	Newton.....	1914. June 25	3	1914. June 28	2	Days. 3	° F. 74
2.....	Wildermuth.....	1912. July 30	1	1912. Aug. 1	1	2	84
10.....	do.....	Aug. 6	1	Aug. 8	1	2	89
T 1787-1.....	do.....	1916. June 14	2	1916. June 19	2	5	82
T 1787-2.....	do.....	June 15	1	June 20	1	5	82
T 1787-3.....	do.....	June 17	2	do..... June 21	1	3 4	81 80
T 1787-4.....	do.....	June 22	1	June 25	1	3	79
T 1787-5.....	do.....	do.....	2	do.....	2	3	79
T 1787-6.....	do.....	do.....	2	June 26	2	4	79
T 1787-7.....	do.....	June 23	1	do.....	1	3	79
T 1787-8.....	do.....	June 24	1	June 27	1	3	80
T 1442 1.....	Gates.....	Mar. 20	14	Mar. 23 Mar. 25 Mar. 26	2 2 1	3 5 6	63 59 58
T 99-3.....	do.....	Apr. 2	1	Apr. 8	1	6	62
T 99-7.....	do.....	do.....	1	Apr. 9	1	8	62
T 100.....	do.....	do.....	4	Apr. 5 Apr. 6	2 1	3 4	60 61
T 1405-1.....	do.....	Mar. 15	7	Mar. 20 Mar. 21	2 1	5 6	67 67
T 1405-2.....	do.....	Mar. 20	18	Mar. 23 Mar. 25	5 2	3 5	63 59
T 1837.....	do.....	July 11	9	July 14	5	3	84
Total or average.....			71		41	3.8	.....

EGG.

The eggs are deposited in the stem of the host plant, and in the case of alfalfa are deposited when the alfalfa has reached a stage of growth about 8 to 10 inches high. The adults always seem to prefer young, new-growing, and succulent alfalfa for oviposition. This apparently is contrary to observations made by Folsom and others that the females choose the older and more mature red-clover stems for oviposition. The eggs are deposited through a round opening in the stem made by the female and are always placed within a cavity made in the pith.

The average length of the incubation period, as given in Table II, for 41 eggs is 3.8 days, with a minimum of 2 days and a maximum of 8 days. While the average time required for incubation is lower during periods of higher temperature, yet this variation is not always due to temperature conditions, for eggs under observation hatched in 3 days during the month of April, when the average mean temperature was 60° F., while others during the month of June often required 4 or 5 days for incubation when the temperature was 20° higher.

It will be noted that these egg-stage lengths compare very favorably with the egg stage as reported by Folsom for Illinois. He found the egg stage to be 5 days in length during May, while during July it was only 3 days.

LARVA.

DURATION OF THE LARVAL STAGE.

The duration of the larval stage is about 35 days under all conditions of temperature and moisture. Table III shows that 35 specimens averaged 34.5 days with a minimum of 24 days and a maximum of 54 days. This wide variation in time is due not so much to temperature as to an inclination of the larva to prolong the fourth instar, even after it is apparently full grown, previous to pupation, as at this time it rests for an indefinite period before the pupa is fully formed and the last larval skin is shed.

TABLE III.—Length of larval stage of the clover stem-borer (*Languria mozdari*) in alfalfa at Tempe, Ariz.

Cage No.	Observer.	Date eggs hatched.	Date larvæ pupated.	Length of larval stage.	Average mean temperature.
				Days.	° F.
10.....	Wildermuth.....	1912. Aug. 8	1912. Sept. 4	27	84
	Gates.....	1915. Apr. 19	1915. May 24	35	67
T 99-3.....	do.....	Apr. 8	May 12	34	62
T 99-5.....	do.....	Apr. 5	May 10	33	63
T 99-7.....	do.....	Apr. 9	May 3	24	64
T 100-1.....	do.....	Apr. 5	May 15	40	64
T 100-2.....	do.....	do.....	do.....	40	64
T 100-3.....	do.....	Apr. 6	May 17	41	65
		1916.	1916.		
T 1823-4.....	Wildermuth.....	June 22	July 23	31	85
T 1823-5.....	do.....	do.....	do.....	31	85
T 1823-7.....	do.....	do.....	Aug. 2	41	86
T 1823-9.....	do.....	June 23	Aug. 7	45	88
T 1823-10.....	do.....	do.....	Aug. 16	54	83
T 1823-13.....	do.....	do.....	do.....	54	83
T 1823-14.....	do.....	do.....	July 28	36	82
T 1823-18.....	do.....	June 24	July 24	30	82
T 1823-19.....	do.....	do.....	Aug. 4	41	85
T 1823-20.....	do.....	do.....	Aug. 7	44	85
T 1823-22.....	do.....	June 30	July 26	26	86
T 1823-25.....	do.....	July 16	Aug. 16	31	83
T 1823-26.....	do.....	do.....	Aug. 25	40	83
T 1823-27.....	do.....	do.....	Aug. 19	34	83
T 1823-28.....	do.....	do.....	Aug. 14	29	83
T 1823-31.....	do.....	do.....	Aug. 21	35	83
T 1823-35.....	do.....	do.....	Aug. 11	25	83
T 1823-37.....	do.....	do.....	Aug. 25	39	78
T 1823-38.....	do.....	do.....	Aug. 21	35	83
T 1823-41.....	do.....	June 18	Aug. 14	27	83
T 1823-46.....	do.....	do.....	Aug. 18	31	83
T 1823-47.....	do.....	do.....	Aug. 12	25	80
T 1823-48.....	do.....	do.....	do.....	25	80
T 1823-49.....	do.....	do.....	Aug. 26	39	82
T 1823-58.....	do.....	June 19	Aug. 16	28	83
T 1823-59.....	do.....	do.....	Aug. 21	33	82
T 1823-62.....	do.....	June 20	Aug. 24	35	82
Average.....	.....	.....	.....	34.5	.....

The larvæ pass through four molts (see Table IV) and five instars. In experiments conducted by the authors and tabulated below only three larvæ were reared successfully from egg to pupa with a complete record of the number of molts and instars. This was due to the fact that the larvæ naturally feed within the alfalfa stem and can not be

continuously observed under these conditions. Since the larvæ also, immediately after molting, consume the cast larval skin, it is impossible to find the remains of the molt by dissecting the stem. An attempt was made, therefore, to secure the number of molts and instars by splitting an alfalfa stem down the center, making an artificial cavity in the split half, and fitting this tightly against the side of a long glass tube. The larva was then placed therein and by these means a continual view of the larva was maintained, and thus in three cases records of molts and instars were obtained. Unfortunately, however, the data regarding the lengths of these instars are doubtless quite inaccurate, since the larvæ appeared to hurry their development and pass through to adults as quickly as possible. Apparently this was due to the fact that the larvæ were under unnatural conditions, such as being exposed to light and the glass. The three specimens reared were undersized, and an attempt at rearing almost a hundred others met with failure.

TABLE IV.—*Molts and instars of the clover stem-borer (Languria mozardi) in alfalfa at Tempe, Ariz., 1916.*

Cage No.	Date egg hatched.	Date of first molt.	Length of first instar.	Date of second molt.	Length of second instar.	Date of third molt.	Length of third instar.
			<i>Days.</i>		<i>Days.</i>		<i>Days.</i>
1.....	Apr. 9	Apr. 14	5	Apr. 17	3	Apr. 21	4
2.....	..do....	..do....	5	..do....	3	..do....	4
3.....	..do....	..do....	5	..do....	3	..do....	4

Cage No.	Date of fourth molt.	Length of fourth instar.	Date of pupation.	Length of fifth instar.	Total length of larval stage.	Average mean temperature.
		<i>Days.</i>		<i>Days.</i>	<i>Days.</i>	<i>° F.</i>
1.....	Apr. 26	5	May 7	11	28	68
2.....	..do....	5	May 10	14	31	69
3.....	Apr. 27	6	May 8	11	29	69

THE LARVAL HABITS.

The larva, upon hatching, at first feeds within a quarter-inch cavity constructed by the adult before depositing the egg, but after a day or so begins to eat its way, first through the pith and later through both the pith and softer inner portions of the wall of the stem until it finally has a large cavity with only the thin hard exterior wall of the stem remaining. The larva gradually enlarges this tunnel, working its way both up and down the stem until often the entire length of the stem is traversed. The length of the tunnel usually is limited only by the length of the individual stem infested. Measurements of these tunnels show maximum lengths to be 30 inches. The larva is especially active and travels up and down the tunnel with a

quick wriggling motion. The wall of the tunnel often becomes so thin as to cause wilting of the plant, and in such cases the stem usually falls to the ground, so that in an alfalfa field damaged by this insect the infested stems nearly always either fall on the ground or lodge one against another.

The larva, upon the completion of its feeding period, constructs a cell within which to pupate. This cell is usually 8 to 10 inches long and is sealed at both ends with frass and excrement mixed with a secretion similar to saliva, which the larva ejects at the time of constructing the cell.

- It is impossible for either the larva or pupa of this species to continue its development after a hay crop is cut and put in the stack or baled. During the fall of 1915 the junior author made many observations bearing upon this point, his record of which follows:

During the past month many stems from hay stacks of the past season's cutting have been dissected. In a large percentage of the stems there has been evidence of Languria injury, and in many of the stems larvæ and pupæ were found. These larvæ and pupæ were all dead and dried up, giving evidence that the development is stopped when the hay is cut and put in the stack. Stalks from hay that has been baled have also been dissected and the above conditions are true of the baled hay also.

PUPA.

DURATION OF THE PUPAL STAGE.

The pupal stage for all temperatures for a total of 130 specimens averaged about 9 days, as is shown in Table I, and also in Table V, which follows. Twenty-six specimens, during the months of July and August, averaged 5.6 days (see Table VI). The minimum length was found to be 3 days during the month of July with a maximum of 18 days during the month of June.

Pupation takes place within the cell constructed by the larva, requiring often several hours for the shedding of the larval skin. The larva first attaches itself by the anal cerci to the bottom of the tunnel, and by means of this attachment the pupa very easily detaches itself from the cast skin. This last larval skin is always found attached at the place mentioned.

The pupa is exceedingly active, and as in the case of the larva moves with freedom up and down this 8 or 10 inch tunnel by means of the wriggling movement which has already been mentioned as being characteristic of the larva.

TABLE V.—Length of pupal stage of the clover stem-borer (*Languria mozardi*) in alfalfa at Tempe, Ariz.

Cage No.	Observer.	Date of pupation.	Date adult issued.	Length of pupal stage.	Average mean temperature.
				Days.	° F.
2.....	Wildermuth.....	1912. Aug. 4	1912. Aug. 14	10	86
10.....	do.....	Sept. 4	Sept. 13	9	75
100.....	J. H. Newton.....	1914. July 30	1914. Aug. 4	5	93
100.....	do.....	July 31	Aug. 5	5	93
	Gates.....	1915. May 28	1915. June 6	8	76
	do.....	May 30	June 7	8	76
T 781.....	do.....	Sept. 22	Sept. 29 (adults).	7	74
T 781.....	do.....	do.....	Oct. 1 (3adults).	9	73
T 996.....	do.....	Oct. 3	Oct. 12	9	71
T 996.....	do.....	Oct. 7	Oct. 17	10	68
T 371.....	do.....	July 26	Aug. 2 (3adults).	8	82
T 394.....	do.....	Aug. 22	Aug. 30	8	84
T 395.....	do.....	Aug. 29	Sept. 5	7	81
T 779.....	do.....	Sept. 5	Sept. 15	10	77
T 779.....	do.....	Sept. 8	Sept. 16	8	76
T 779.....	do.....	Sept. 10	Sept. 19	9	77
T 779.....	do.....	Sept. 12	Sept. 20	8	77
T 779.....	do.....	do.....	Sept. 22	10	78
T 994-1.....	do.....	Oct. 1	Oct. 10	9	73
T 994-2.....	do.....	Oct. 8	Oct. 18	10	69
T 994-3.....	do.....	Oct. 9	Oct. 20 (2adults).	11	68
	do.....	June 1	June 8	7	76
	do.....	June 15	June 24	9	82
	do.....	do.....	June 25	10	82
T 393.....	do.....	Aug. 20	Aug. 29	9	84
T 781.....	do.....	Sept. 20	Sept. 29	9	76
T 99-2.....	do.....	May 10	May 22	12	72
T 99-3.....	do.....	May 12	May 23	11	72
T 99-5.....	do.....	May 10	May 19	9	72
T 100-1.....	do.....	May 15	May 24	9	71
T 100-2.....	do.....	do.....	May 29	14	72
T 100-3.....	do.....	May 17	May 25	8	71
		1916.	1916.		
T 1671-1.....	Wildermuth.....	May 9	May 22	13	71
T 1671-2.....	do.....	do.....	May 23	14	71
T 1671-3.....	do.....	May 13	do.....	10	70
T 1671-4.....	do.....	May 15	May 25	10	69
T 1671-5.....	do.....	do.....	May 24	9	69
T 1671-6.....	do.....	do.....	May 26	11	68
T 1671-7.....	do.....	do.....	May 25	10	69
T 1671-8.....	do.....	May 16	May 24	8	70
T 1671-9.....	do.....	May 18	May 30	12	69
T 1671-10.....	do.....	do.....	May 29	11	68
T 1671-11.....	do.....	do.....	May 31	13	69
T 1671-12.....	do.....	May 19	June 6	18	70
T 1671-13.....	do.....	do.....	May 31	12	69
T 1671-14.....	do.....	do.....	do.....	12	69
T 1671-15.....	do.....	do.....	May 30	11	68
T 1671-16.....	do.....	May 22	June 1	10	69
T 1671-17.....	do.....	do.....	do.....	9	69
T 1671-18.....	do.....	do.....	May 31	9	69
T 1671-19.....	do.....	May 23	June 3	11	69
T 1671-20.....	do.....	do.....	do.....	11	69
T 1671-21.....	do.....	May 24	June 5	12	70
T 1671-22.....	do.....	May 25	June 6	12	71
T 1671-23.....	do.....	May 26	do.....	11	71
T 1671-25.....	do.....	do.....	do.....	11	71
T 1671-26.....	do.....	May 27	do.....	10	72
T 1671-27.....	do.....	do.....	do.....	10	72
T 1671-28.....	do.....	do.....	do.....	10	72
T 1671-29.....	do.....	May 29	do.....	8	73
T 1671-30.....	do.....	do.....	June 7	9	73
T 1671-31.....	do.....	do.....	June 6	8	73
T 1671-32.....	do.....	do.....	do.....	8	73
T 1671-34.....	do.....	do.....	do.....	8	73
T 1671-35.....	do.....	do.....	June 7	9	73
T 1671-36.....	do.....	do.....	June 6	8	73
T 1671-37.....	do.....	do.....	do.....	8	73
T 1671-38.....	do.....	do.....	do.....	8	73
T 1671-39.....	do.....	do.....	June 7	9	73

TABLE V.—Length of pupal stage of the clover stem-borer (*Languria mozdardi*) in alfalfa at Tempe, Ariz.—Continued.

Cage No.	Observer.	Date of pupation.	Date adult issued.	Length of pupal stage.	Average mean temperature.
		1916.	1916.	Days.	° F.
T 1671-40.....	Wildermuth.....	May 29	June 7	9	73
T 1671-41.....	..do.....	..do.....	..do.....	9	73
T 1671-42.....	..do.....	..do.....	..do.....	9	73
T 1671-43.....	..do.....	May 30	June 6	7	73
T 1671-44.....	..do.....	..do.....	June 8	9	74
T 1671-45.....	..do.....	..do.....	..do.....	9	74
T 1671-46.....	..do.....	May 31	June 9	9	75
T 1671-47.....	..do.....	June 1	..do.....	8	76
T 1671-48.....	..do.....	..do.....	June 8	7	75
T 1671-49.....	..do.....	..do.....	June 9	8	76
T 1671-50.....	..do.....	..do.....	June 8	7	75
T 1671-51.....	..do.....	..do.....	June 9	8	76
T 1671-52.....	..do.....	..do.....	..do.....	8	76
T 1671-53.....	..do.....	June 2	June 10	8	77
T 1671-54.....	..do.....	June 3	June 12	9	78
T 1671-55.....	..do.....	..do.....	..do.....	9	78
T 1671-56.....	..do.....	..do.....	..do.....	9	78
T 1671-57.....	..do.....	June 5	June 14	9	79
T 1671-58.....	..do.....	..do.....	June 12	7	79
T 1671-59.....	..do.....	..do.....	..do.....	7	79
T 1671-60.....	..do.....	..do.....	June 14	7	79
T 1671-60.....	..do.....	..do.....	June 12	7	79
T 1671-61.....	..do.....	..do.....	..do.....	7	79
T 1671-62.....	..do.....	..do.....	..do.....	7	79
T 1671-63.....	..do.....	..do.....	June 14	9	79
T 1671-64.....	..do.....	June 6	..do.....	8	80
T 1671-65.....	..do.....	..do.....	..do.....	8	80
T 1671-66.....	..do.....	..do.....	..do.....	8	80
T 1671-67.....	..do.....	June 7	..do.....	7	80
T 1671-68.....	..do.....	..do.....	..do.....	7	80
T 1671-69.....	..do.....	..do.....	..do.....	7	80
T 1671-70.....	..do.....	June 9	June 16	7	81
T 1671-71.....	..do.....	..do.....	..do.....	7	81
T 1671-72.....	..do.....	June 10	June 17	7	82
T 1671-73.....	..do.....	June 12	..do.....	5	83
Average.....	.....	.....	.....	9	.....

TABLE VI.—Length of pupal stage of the clover stem-borer (*Languria mozdardi*) in alfalfa at Tempe, Ariz., 1916.

Cage No.	Observer.	Date of pupation.	Date adult issued.	Length of pupal stage.	Average mean temperature.
				Days.	° F.
T 1823-4.....	Wildermuth.....	July 23	July 26	3	88
T 1823-5.....	..do.....	..do.....	..do.....	3	88
T 1823-7.....	..do.....	Aug. 2	Aug. 9	7	85
T 1823-9.....	..do.....	Aug. 7	Aug. 12	5	85
T 1823-10.....	..do.....	Aug. 16	Aug. 23	7	80
T 1823-14.....	..do.....	July 28	Aug. 2	5	89
T 1823-18.....	..do.....	July 24	July 30	6	86
T 1823-19.....	..do.....	Aug. 4	Aug. 9	5	87
T 1823-20.....	..do.....	Aug. 7	Aug. 14	7	84
T 1823-22.....	..do.....	July 26	Aug. 2	7	87
T 1823-25.....	..do.....	Aug. 16	Aug. 23	7	80
T 1823-26.....	..do.....	Aug. 25	Sept. 1	7	84
T 1823-27.....	..do.....	Aug. 19	Aug. 26	7	81
T 1823-28.....	..do.....	Aug. 14	Aug. 21	7	79
T 1823-31.....	..do.....	Aug. 21	Aug. 28	7	83
T 1823-37.....	..do.....	Aug. 25	Sept. 1	7	84
T 1823-38.....	..do.....	Aug. 21	Aug. 28	7	83
T 1823-41.....	..do.....	Aug. 14	Aug. 22	8	74
T 1823-46.....	..do.....	Aug. 18	Aug. 26	8	80
T 1823-47.....	..do.....	Aug. 12	Aug. 19	7	80
T 1823-48.....	..do.....	..do.....	..do.....	7	80
T 1823-49.....	..do.....	Aug. 26	Sept. 2	7	85
T 1823-58.....	..do.....	Aug. 16	Aug. 23	7	80
T 1823-59.....	..do.....	Aug. 21	Aug. 28	7	83
T 1823-62.....	..do.....	Aug. 24	Aug. 30	6	84
T 1490.....	Gates.....	Apr. 28	May 8	10	72
Average.....	.....	.....	.....	6.5	.....

ADULT.

The adult, after issuing from the pupa, often spends a period of time varying from two days to several weeks in the cavity within the alfalfa stem. The adults arising from the first generation nearly all emerge within a few days after becoming mature, while those issuing in late fall often remain for weeks within the stems. The beetle escapes from the cavity by eating an irregular opening in the wall of the stem. This opening is usually about one-fourth larger than the diameter of the adult itself.

When issuing from the pupa, the adult is very light colored. The wing coverings are soft and of a whitish-yellow color. The head and thorax are light orange; the eyes and antennæ are black, which causes them to stand out distinctly against the general body color. In from 4 to 6 hours the wing coverings become a shining black, and the head and thorax gradually turn a much darker orange color and finally reddish. Usually within a day's time the adult has completely hardened and taken on all the characteristic adult colors.

In the case of the earlier generations, the adults after issuing feed for a period of 6 to 8 days, after which copulation takes place, and in from 3 to 7 days more the act of oviposition is accomplished. The adults often copulate several times before eggs are finally deposited.

FEEDING HABITS OF ADULTS.

In the past, the adults have generally been considered to feed upon pollen only, and while this is their important food, yet as Folsom first reported, they are often, in the spring of the year, observed to eat the foliage of their host plant. The authors have also observed the adults feeding at the oviposition puncture. This fact in itself is significant because of the size of the opening which the female makes previous to oviposition. Often this opening is so large that the stem splits and breaks at this point. Although it is likely that the adults will feed upon pollen of almost all available blossoms, yet a list of those plants upon which it has been known to feed is of considerable interest. The authors have noted it feeding on the bloom of alfalfa, yellow sweet clover, wild barley, sunflower, and prickly lettuce. Other members of the Bureau of Entomology have made records on the feeding habits of the adults as follows:

T. H. Parks.....	Red clover.
W. E. Pennington.....	Wheat heads.
L. P. Rockwood.....	Corn silk.

THE ADULTS SECLUSIVE.

The adults are very seclusive in their habits. They usually make use of the early morning hours for their feeding, while the act of oviposition nearly always is accomplished in the late evening or at

night. They invariably seem to avoid excessive temperature and sunlight, and when disturbed immediately drop to the ground and feign death. They remain in this motionless position for a long period of time and in fact almost seem to know instinctively when a person is looking at them.

OVIPOSITION.

The adults prefer young succulent alfalfa stems for oviposition. The female before ovipositing prepares a rather large nidus in the stem. This consists of two parts: The outer larger portion which is about one-eighth of an inch square and is only eaten through the epidermis and plant tissues immediately adhering thereto, and a smaller round opening in the center of this outer square about one-sixteenth of an inch in diameter, which extends to the pith of the stem. The adult is thus enabled to introduce her head and thorax within the stem and hollow out a cavity in the pith for placing the egg. This cavity is usually one-fourth of an inch in length and evidently is for the purpose of affording the newly hatched larva a place for locomotion and feeding.

After preparing the egg receptacle, the female deposits the egg, usually just below the external orifice and on the opposite wall of the stem. After ovipositing, the female teases out the tissues on the edge of the inner or round opening so that they practically close the hole. A fresh oviposition puncture is almost white or colorless in appearance, but after 36 to 48 hours it becomes a dark brown spot, and at all times is conspicuous and easily noted, especially after the dark color has been assumed. During periods of heavy summer rainfall and excessive humidity the alfalfa stem often splits open each way from the oviposition puncture, and the stem breaks over and is entirely destroyed. In this case, the larva fails to develop.

During the authors' observations and those of other members of the bureau, more than one egg has never been noted as being placed through one oviposition puncture. Two oviposition punctures sometimes occur in the same stem, but in each case one larva always destroys the other, and thus only one beetle develops in a single alfalfa stalk. A. A. Girault (15), who has made an interesting observation upon the oviposition habits of this species, has noted at least 15 eggs deposited through a single opening within the stem of a species of *Leucanthemum*. This is described by him as follows:

After preparing the nidus, the female leisurely walks up the stem the length of her body, and after feeling a little, fits the tip of the abdomen into the excavation and places an egg. After depositing she wheels in her tracks with almost military precision, simply reversing her position and commences to prepare another place for an egg in the same excavation. The female works with economy, wheeling about

each time, so that the tip of the abdomen approached the excavation at each deposition, and then again to the rear, so that the jaws would strike the excavation when about to prepare a place for the next egg. Thus, in preparing the cavity, the beetle was facing up, with her body below it; when about to deposit the first egg she simply moved forward the length of her body, and afterwards simply wheeled in her tracks, when about to prepare a place for the second egg. The succeeding depositions were executed by wheeling about each time. Therefore, each completed movement, consisting of two wheels to the rear, accomplished the deposition of two eggs, occupying about $4\frac{1}{2}$ minutes.

SEASONAL HISTORY.

A study of the seasonal history of this insect in the southwestern United States is especially interesting because of the bearing it has upon the control of the species.

There is present, especially in the Salt River Valley of Arizona, along ditch banks, fence rows, and all waste places in the spring of the year, a luxuriant growth of yellow sweet clover (*Melilotus officinalis*) (Pl. I, fig. 1). Hibernating beetles, upon their appearance in early March, find this sweet clover growing in the immediate vicinity of their winter quarters, and consequently, when the reproductive instinct asserts itself, they begin ovipositing in this plant, the growth of which is at the proper stage for their purpose. The first generation of these beetles is, therefore, passed almost entirely upon this plant.

The date of emergence of the beetles depends quite largely upon conditions of temperature. During the spring of 1915, on March 12, beetles were found by the senior author to be still hibernating and they did not begin their activities for at least 10 days following this date. During 1916, on the other hand, eggs were found in yellow sweet clover by the junior author on March 9, and in the same year larvæ were taken in the field on March 15. The average mean temperature, at Tempe, Ariz., from February 1, 1915, to March 12, 1915, was 52° F., while the average mean temperature from February 1, 1916, to March 9, 1916, was 59° F.

In the eastern United States this beetle has only one generation annually. A review of observations by several writers shows that hibernating beetles come forth in late April or early May, eggs are deposited soon thereafter, and by late June larvæ are usually abundant. By August 1 pupæ are present and in early August the new adults begin to appear. These continue to emerge until late September, and soon after the appearance of heavy frosts the species is again in hibernation.

This insect in the southwestern United States has three distinct generations annually. As has already been mentioned, the first generation is passed almost exclusively upon yellow sweet clover, while the second and third generations are passed upon alfalfa and other plants, the majority of which are weeds. Where alfalfa is found, in



FIG. 1.—IRRIGATION DITCH OVERGROWN WITH YELLOW SWEET CLOVER AND COMMON MALVA, GIVING RISE TO FIRST GENERATION OF THE CLOVER STEM-BORER (*LANGURIA MOZARDI*).



FIG. 2.—IRRIGATION DITCH BANK FENCED AND PASTURED BY THE USE OF SHEEP, ELIMINATING WEEDS AND WASTE GROWTH AND PREVENTING INSECT DEVELOPMENT IN SUCH LOCATIONS.

THE CLOVER STEM-BORER.

the month of March and early April, of the proper size and maturity, beetles, which have come from their hibernation quarters, will also oviposit in alfalfa, and a small percentage of them have been found ovipositing in the common mallow (*Malva rotundifolia*).

Adults of the first generation are found issuing in early May, the earliest date upon which adults have been observed to issue being April 26, 1916, by the junior author. In a week to 10 days after issuing, adults again are ovipositing; the second generation immediately follows, and by early June larvæ of this generation are found in immense numbers in infested alfalfa fields. It is the first generation, and the early broods of the second generation that do the largest damage to alfalfa, since the third generation usually is parasitized quite heavily. Beetles of the second generation begin appearing any time after the middle of July and start oviposition for the third generation which gives rise to beetles early in the fall. It is thought that at times this fall generation of beetles also oviposits before going into winter quarters, yet it has been impossible to be sure of this owing to the fact that later-appearing beetles of the second generation have also been known to survive until early September and continue their oviposition activities until that date. The latest date on which eggs have been taken in the field is September 6, 1916, while pupæ have been dissected from field-grown alfalfa stems as late as the last week in October.

It is thus to be noted that there is a considerable intermingling of the second and third generations, so that under field conditions they are not separate and distinct. Both the parent beetles and beetles of a new generation may be found ovipositing in the same field, and it was only by careful cage observations that the three distinct generations were secured. While indications point toward a possible fourth generation, yet this was not conclusively proven to the satisfaction of either author. By early November of most years beetles have gone into hibernation and can not be found in the field.

HIBERNATION.

These borer beetles have been observed hibernating in almost any place where they have sufficient cover to protect them from the freezing temperatures of winter.

C. M. Packard, of the Bureau of Entomology, has found them at Hagerstown, Md., hibernating under stones in wheat fields and in grass along railroad right of ways. D. J. Caffrey captured two adults at the edge of a wheat stack at Tempe, Ariz., while T. S. Wilson, likewise of the bureau, found an adult of this species in wild barley along a fence row.

The junior author maintained a large winter cage containing beetles of the clover stem-borer, and from these cage records it was

observed that from November 26 to February 18 these beetles were found hibernating "under clods, leaves, sticks, etc., often going into loose ground but generally only under some surface rubbish where most of the time is spent in a semidormant condition." Hibernating adults have been taken by the senior author along fence rows overgrown by weeds or rubbish of any kind.

A few records are available showing that this insect, on certain occasions, passes the winter in the larval stage. Dr. F. H. Chittenden found larvæ remaining in stems of ragweed from November to April, while the junior author dissected a full-grown live larva from an alfalfa stem the latter part of December, 1915, and this larva when placed in another stem continued its development, pupating early in March. It is thus seen that it is altogether possible for this species to hibernate as a larva, but its normal habit is to pass the winter as an adult.

REARING METHODS.

Cages for confining adults for oviposition were made by placing two glass gas-light chimneys end to end and fastening them by adhesive tape. These were then placed over an alfalfa plant growing under natural conditions, and the upper end of the chimney was covered by muslin. Into this the adults were placed and allowed to remain overnight. Thus, any eggs deposited were secured almost immediately after being laid. The eggs were then removed from the alfalfa stalk and placed either on moist blotting paper or in a small cavity within a plaster of Paris salve box. The larvæ, upon hatching, were placed within stems of alfalfa. These stems were dissected day after day, and each day the larvæ placed in fresh stems. A small plug of absorbent cotton was used to close the upper end of the stem, while the lower end was placed in a vial of water.

Pupæ kept within small (9 by 36 mm.) vials containing a piece of slightly moist blotting paper developed very successfully. As has been mentioned elsewhere in this paper, a great many attempts were made to rear larvæ by placing them within a split alfalfa stem, the open side of which was placed against the side of a glass tube and the lower end in a small vial of water, the larvæ in this cage being continually under observation. Although these conditions seemed to be very abnormal, yet a certain amount of success was experienced by the use of this type of cage.

Generation records were secured by placing a wire screen cage (3 by 3 by 3 feet) (fig. 5) over alfalfa growing under normal conditions. Adults were placed in this cage for a definite period of time and then removed. Additional records were obtained by stem dissections at the time pupæ were thought to be present, and these were used for securing the adults of a new generation.

NATURAL ENEMIES.

TOADS.

The clover stem-borer, like many of our older native species, is in a great majority of cases kept in check by its natural enemies. During the past few years practically every toad that has been killed by any of the men carrying on this investigation has had several adults of this beetle within its stomach. Tyler (11) has reported this species as being present in the stomachs of toads. Doubtless these batrachians eat a great many *Languriae* during the course of a year, and because of the fact that toads are largely insect feeders, they are deserving of careful protection from farmers.

BIRDS.

The Bureau of Biological Survey has found specimens of *Languria mozardi* in the stomachs of the following species of birds: Traill flycatcher (*Empidonax trailli*), starling (*Sturnus vulgaris*), meadowlark (*Sturnella magna*), mockingbird (*Mimus polyglottos*), Carolina wren (*Thryothorus ludovicianus*), and robin (*Planesticus migratorius*).

PARASITES.

The most important natural enemies, however, that aid in controlling this species are its hymenopterous parasites.

In his early observations upon this species, Prof. Comstock (8, p. 199) noted that:

Two parasites were found within the burrows of the stalk borers, the one a small black chalcid, the dark, naked pupa of which was often met with, and the other a yellowish ichneumonid, the pupa of which was inclosed in a delicate white silken cocoon.

In 1890 Weed (13) also reported a black chalcid as an external pupal parasite. This was doubtless the same species as that reported by Comstock a good many years previously. Folsom (16), in 1909, again noted the black chalcid in considerable numbers, this being evidently the same one referred to by Weed and Comstock. Folsom also took an ichneumonid cocoon from a *Languria* burrow which disclosed an adult after a pupal period of 4 days. Among the Bureau records we find one by C. V. Riley, who reared a scelinid larval parasite.

HABROCYTUS LANGURIAE.

The authors of the present paper have noted three rather important parasites of this species. *Habrocytus languriae* Ashm. (fig. 6) is without doubt of the greatest importance. Often as high as 30 per cent of the larvæ of *Languria* are parasitized by this species.

The *Habrocytus* adult oviposits through the wall of the alfalfa stem into the tunnel occupied by the *Languria* larva, and within

from 2 to 3 days the parasite larva hatches and immediately searches out its *Languria* host.

The duration of the larval period during the month of June was found to be 8 days, with an average mean temperature of 81° F., while the larval stage length of another specimen was 13 days, from March 28 to April 10, during a mean temperature of 60° F.



FIG. 6.—*Habrocytus languriae*, a parasite of the clover stem-borer.

The pupa is free and the stage is passed within the *Languria* burrow. The pupal stage length of 6 specimens averaged 9 $\frac{2}{3}$ days, while a single specimen, during the month of April, had a pupal stage length of 19 days. The records are given in Table VII, which follows:

TABLE VII.—Length of pupal period of the parasite *Habrocytus languriae*.

Pupated.	Adult issued.	Pupal period.	Average mean temperature.
1916.	1916.	Days.	° F.
May 8	May 17	9	72
Do.	May 16	8	72
May 9	May 18	9	72
May 13	May 24	11	70
May 16	May 27	11	69
June 30	July 10	10	86
April 10	April 29	19	68

OTHER PARASITES.

The next most important parasite reared from *Languria* larvæ was *Heterospilus* sp. This was first reared by the senior author in 1912, and again in September, 1915, by the junior author. Three specimens of *Eurytoma* sp. were reared by the junior author during August, 1915, from *Languria* larvæ, while the senior author in May, 1916, reared the same species from the larvæ of *Habrocytus languriae*. In this case it had a larval stage of 10 days and a pupal stage of 13 days, and, as is noted, was a distinctly secondary parasite. The value of this parasite, therefore, in keeping *Languria mozdardi* in check is questionable, since it is both primary and secondary in habits. The

same is true of the parasite *Eupelmus allynii* French. This species was reared by the senior author during August, 1912, as both a primary and secondary parasite of *Languria* feeding upon the *Languria* larvæ and also upon larvæ of the primary parasite (*Habrocytus languriae*). The pupal stage of this *Eupelmus* was 10 days during the month of August.

While the primary parasites undoubtedly are of considerable benefit in controlling this beetle, it must not be supposed that vigorous efforts on the part of the alfalfa grower are not necessary to effect the satisfactory subjection of the pest.

CONTROL MEASURES.

As early as 1879 Prof. Comstock (8, p. 200) gave us the key to the control of this species when he stated:

It seems probable that where clover is regularly cut in early summer and again in fall this insect will not increase to any alarming extent; but where this is neglected, or where there is much waste clover, it may do considerable damage.

In other words, Prof. Comstock recognized the fact that in case clover was cut when it was in a prime condition, a large number of the *Languria* borer larvæ within the clover stems would be destroyed.

As regards the control of this species upon red clover, Prof. Folsom (16) writes as follows:

Every year the farmer unknowingly kills off large numbers of these insects when he cuts his hay crop, whether he cuts it early or late, for in the latter part of June and throughout July in this latitude the great majority of the insects are inside the clover stems as larvæ or pupæ. The old beetles from the previous year are practically gone by July 5, and the new beetles do not issue from the stems until about the 1st of August. If the cutting of the hay crop is neglected, however, and left far into July, much of the clover will be flat on the ground from the work of this insect. I had this tested on the university farm, and when the clover was cut, heard from the man who mowed the field certain appropriate comments upon the amount of clover which had lodged.

If the red clover is cut when it should be—to make the best fodder—only about three stems in a hundred of the new growth will show the insect. To find many larvæ in July and early August one has to search in uncut field clover or in clover growing wild on the border of a field or by the side of the road or the railroad track. The practice of mowing and destroying volunteer clover is well worth the little time that it takes.

Owing to the habits of this insect, it has not been found possible to use any poison against it for purposes of control. The means at our disposal is a regulation of the general farm practices which, of course, takes into consideration the habits and life history of the insect so that the larvæ will be destroyed before completing their development either in the main body of alfalfa and clover fields or in neglected waste places.

DESTROYING SWEET CLOVER, WEEDS, AND WASTE ALFALFA.

As has been already pointed out, the first brood of the clover stem-borer in the southwestern United States is largely passed upon yellow sweet clover, while portions of the other broods in this same section, as well as other sections of the country, develop upon various kinds of weeds. It is thus readily seen that if that portion of the first generation or brood upon yellow sweet clover is entirely eliminated by cutting down, pasturing, or otherwise destroying all sweet clover growing along ditch banks, roadsides, and fence rows, then there will be many less females to oviposit in the oncoming crops of alfalfa or clover.

A great many farmers, in cutting either an alfalfa or clover hay crop, allow a strip to remain uncut along fence rows and ditch banks, and in these places all borers that are present and which are able to escape their parasites are allowed to go through to the adult stage in a thrifty condition. Thus, such places serve as continual sources of infestation for the new coming alfalfa crop. Where stock is available, a great many farmers are in the habit of turning cattle into a hay field for a few days immediately after removing a hay crop, allowing these to clean up completely all alfalfa which remains standing or falls on the ground. This is a very excellent practice and one that should be encouraged at all times. In case cattle are not available, then this waste alfalfa or red clover should be cut either by scythe or hand sickle and removed from the ground with the hay crop.

In irrigated regions where the farmer is continually confronted with weeds, clover, and waste alfalfa growing upon ditch banks, two very excellent methods of control for keeping these places free from weeds are available: One is to cultivate the ditches and ditch banks continually, thus keeping down all foreign growth; another method, and one that can be accomplished with benefit to the rancher, is that of fencing all ditch banks and pasturing, preferably by sheep, which are adept at keeping down waste growth. (See Pl. I, figs. 2 and 3.)

HARVESTING METHODS.

It is well to point out at this time that where alfalfa or clover is pastured the borers are unable to develop. It is only in waste places or where haying is practiced that they are able to reach maturity.

HAYING.

If the farmer will acquaint himself with the nature of the injury done by this insect in either alfalfa or red clover hay and the appearance of the egg holes in the stems, then when these are found in numbers he will take pains to cut his alfalfa or red clover when it is in the height of its nutritive value, which in the case of red clover is

when the crop is in full bloom, and in the case of alfalfa when the crop is about one-tenth in bloom. Then, provided that the land has in the past received proper cultivation and crop rotation, and the crop is a thrifty growing one, the borers will not have been able to develop to adults before the hay crop is removed, and thus, as has been shown in the previous discussion of larval habits, all larvæ and pupæ will be destroyed.

Where an alfalfa or clover crop is let go to seed, conditions are ideal for the development of adults, and if the farmer is producing seed, there is no remedy for this except that the beetle must be controlled in all waste places and adjoining hay fields. If this practice is followed, there will be but few beetles to oviposit in seed fields, and hence the damage will be reduced to a minimum.

BURNING RUBBISH.

Since these beetles pass their winter stage under rubbish, grass, etc., the farmers of any section of the country should make it a point, each fall or early in the winter when the frost has killed all weeds and grasses, to burn or otherwise destroy all grass, weeds, and rubbish in waste places such as roadsides and ditch banks, and eliminate these places of hibernation, thus reducing the numbers of beetles as well as other insect pests.

CROP ROTATION.

In the red clover growing sections of the country, proper systems of rotation have already been well developed and are used, as a general rule; but in a great many of the large alfalfa districts of the West and Southwest, farmers are too prone to allow alfalfa to stand in the same field for a number of years without rotating it with some other crop or crops. Where such conditions prevail, the land becomes "alfalfa-sick," and the crop does not grow in as thrifty a manner as it would were the land planted to some other crop during a certain series of years. In the clover districts this is well emphasized, and alfalfa growers should take a lesson from clover growers.

Where alfalfa is to be used as the hay crop, a rotation can be arranged to cover a much longer period of years than where red clover is used as a hay crop, since alfalfa can be left on the ground without a reduction in stand for a much longer time than can red clover. The advent of Egyptian cotton culture in the valleys of the southwestern United States is doing much toward readjusting the plan of farm work, and the time is not far distant when a system of crop rotation will be evolved that will include both cotton and alfalfa in the rotation plan to the benefit of both crops and the elimination of many insect pests affecting them.

SUMMARY.

The clover stem-borer has been known for a good many years as an enemy of red clover. Recently it has attracted attention as an enemy of alfalfa, especially in the southwestern semiarid regions of the United States where irrigation has made possible the growing of large acreages of alfalfa. The larvæ or young of the borer injure the plant by boring out the center of the stems of both alfalfa and clover.

The insect is widely distributed throughout the United States and parts of Canada and Mexico, and has a large cosmopolitan list of food plants.

The eggs are deposited in the stem through a small opening prepared in the host plant by the adult female.

The larvæ are found feeding within the stems of the host plant, first upon the pith and then upon the plant tissues surrounding the pith, and they move up and down the stem throughout its length.

The pupal stage is passed in cells, 6 to 8 inches long, within the stems where the larvæ have passed their lives.

The adults hibernate under rubbish along fence rows, ditch banks, or other waste places.

In the eastern United States this insect has one generation each year; in the southwestern United States there were found to be three distinct generations each year. The first generation in the southwestern United States is passed almost entirely upon yellow sweet clover, and the beetle can be greatly reduced in numbers by destroying this weed pest.

The injury to alfalfa and red clover can be partially eliminated by destroying sweet clover, weeds, and waste alfalfa. The damage also can be reduced greatly by cutting a hay crop before the larvæ have had an opportunity to complete their development. The practicing of proper methods of crop rotation as well as cleanliness of farming, such as burning rubbish, etc., will also cause a reduction in numbers of this beetle. The beetle is unable to develop where pasturing is practiced continuously.

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Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.

PROFESSIONAL PAPER

July 28, 1922

THE GREEN JUNE BEETLE

By

F. H. CHITTENDEN, Entomologist in Charge, and
D. E. FINK, Entomological Assistant, Truck
Crop Insect Investigations

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INTRODUCTION.

The green June beetle is one of the best known of Southern insects and is quite common in the Eastern States from New Jersey and southern Illinois southward. It occurs also somewhat commonly on Long Island, in southern Connecticut, and in the neighborhood of New York City. Injuries by this insect were at one time erroneously believed to be practically confined to the beetle, since the larvæ feed normally and largely on humus or mold, or soil rich in decaying vegetable matter, and in stable and lot manure.

The beetles injure fruits of various kinds, including grapes, peaches, raspberry, blackberry, apple, pear, quince, plum, prune, apricot, and nectarine, and frequently obtain nourishment as well on the sap of oak, maple, and other trees, and on the growing ears of

¹ *Cotinis nitida* L. (formerly known as *Allorhina nitida*); family Scarabæidae, order Coleoptera.

² Investigations of the life history and habits have been conducted by the junior author in tidewater Virginia, and by the senior author in the District of Columbia and near-by points in northern Virginia. Similar investigations have been conducted by Mr. J. J. Davis, Bureau of Entomology, at Louisville, Ky., La Fayette, Ind., and elsewhere, and by Mr. Philip Luginbill, Cereal and Forage Insect Investigations, at Columbia, S. C. Many of the notes on injuries and habits made by these observers have been used in the preparation of this publication.

corn. The beetle has been observed also eating a fungus on quince trees.

Indirectly the larvæ or grubs are responsible for considerable injury on the grounds of golf clubs and on lawns. They injure also corn, oats, sorghum, and alfalfa. Vegetables of many kinds are frequently attacked and injuries have been reported to celery, parsley, beets, turnip, lettuce, endive, strawberry, eggplant, potato, beans, carrot, parsnip, collards, peas, and other plants. Among ornamental plants, dahlia, rose, violet, geranium, hyacinth, and privet are attacked. The larvæ attack other forms of plants with comparatively succulent herbaceous stalks, and such crops as melons, tomato, and young sweet corn. The natural food plants are undoubtedly different varieties of grasses, cultivated forms, including bluegrass, evidently being more affected than those which are allowed to grow wild and become weedy.

The life history of the green June beetle has not hitherto been followed out. Many interesting facts have been learned in regard to its habits in its active stages, and an account of its natural enemies and other data have been brought together, thus adding much to our hitherto meager knowledge of its life economy. There is no longer any doubt that the insect is more injurious in its larval stages than as a beetle. Indeed the species does far more injury to vegetable and truck crops, according to records which have been made, than to fruits.

CLASSIFICATION.

The genus to which this species belongs is a member of the tribe Cetoniini, of the family Scarabaeidae, in which the epimera of the mesothorax are visible from above. A subtribe of the same name has the elytra sinuate on the sides, and the mesosternum always prominent. The mandibles are feeble, in great part membranous, and the last spiracle is situated midway between the anterior and posterior margins of the segment. The prothorax is lobed at the base, covering the scutellum. The genus *Cotinis* may further be separated from related genera in having the clypeus armed with a short horn, which is more prominent in the male.

According to Bates (16)³ the North American species classified under the genus *Allorhina* are placed in the genus *Cotinis* of Burmeister (1842). What Bates (16, p. 345-346) says in regard to *C. mutabilis* and *C. sobrina* is well worth quoting in this connection as bearing about equally well upon the relationship of *mutabilis* and *nitida*. He writes:

After careful examination of about 250 examples I have come to the conclusion that the characters adduced by Burmeister to distinguish this species

³ Figures in parentheses refer to "Literature cited," p. 49.

from *C. sobrina* are in the highest degree inconstant, and that there are no means of defining the two species. All that can be said is that *C. mutabilis* is, in the great majority of its individuals, larger and broader. The shape of the clypeal horn is very variable, and its varieties do not correspond with variations in size, breadth, and color, large and robust specimens of the typical *mutabilis* having the horn either dilated toward the apex, parallel-sided, or triangular, and the same diversities may be seen in small and slender oblong examples of *C. sobrina*. It is the same with regard to form and color; for it is far from the case that the large and broad examples (*C. mutabilis*) only are unicolorous; smaller and narrower individuals exist equally unicolorous and of nearly all the color-varieties displayed by the larger set. It is true that the variegated varieties described by Burmeister under *C. sobrina* are, as a rule, smaller than the others; but they are connected by the most finely graduated series of variations, so that it is impossible to draw a distinction between the two series. The case is a very difficult one to deal with. It would not be satisfactory, and scarcely practicable, to include under one specific diagnosis all the numerous varieties, some of which are possibly local, thus presenting an interesting study to future collectors and students; the better course seems to be to treat the more distinct separately, giving the localities of each.

DESCRIPTIVE.

The beetle (fig. 1) is larger and more robust than the common brown May and June beetles (*Phyllophaga*), measuring from three-fourths to a full inch or more in length, and about one-half inch wide. The color varies from dull brown with irregular stripes of green to beautiful uniform velvet green, the margins of the body being usually light brown varying to orange yellow. The lower surface is metallic greenish or yellow. or metallic dark brown with a yellow-green tinge.

The full-grown larva is illustrated in figure 2 and Plate II. When compared with that of *Phyllophaga* (fig. 3), it will be noticed that the former is stouter with shorter legs.

The pupa, which is also stouter, is shown alone and within its pupal case or cocoon in Plate III, A, B. The pupa of *Phyllophaga* (Pl. III, C) differs from the pupa of *Cotinis* in that the pupa of the former is not encased in a regular cocoon.



FIG. 1.—Adult of green June beetle (*Cotinis nitida*) of a type showing narrow margin about elytra and narrow margin on anterior half of thorax. One-third enlarged.

HABITS DIFFERENT FROM THOSE OF WHITE GRUBS.

The green June beetle differs from the May beetles in habits, being strictly diurnal and most active in the heat of the day, whereas

the typical winged *Phyllophaga* is nocturnal. There is a still more striking difference in that the larva of the green June beetle travels on its back, whereas that of *Phyllophaga* either progresses on its side or, where possible, on the abdomen with the aid of the legs.

The larva (fig. 2), particularly when mature, differs from the common white grub of the genus *Phyllophaga* in being larger, and pro-

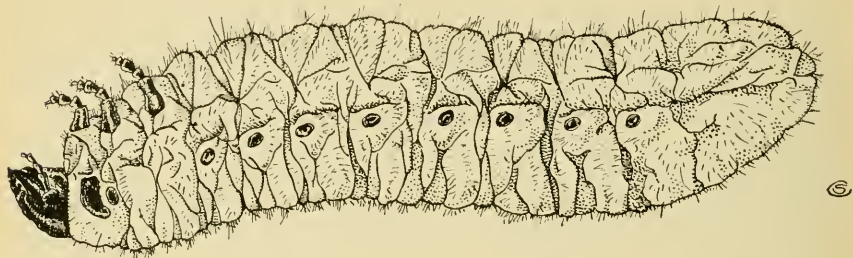


FIG. 2.—Full-grown larva of green June beetle in natural position crawling on its back. Twice natural size.

portionately so, as regards the size of the adults. It is also more robust and more nearly cylindrical; its legs are considerably shorter and its mandibles and other mouth parts smaller. It differs also in the possession of stiff ambulatory bristles, which more or less closely cover the dorsum and enable the insect to crawl, not on its side, as is the case with the *Phyllophaga* larva, but upon its back. This is ac-

complished by alternate contraction and expansion of the segments of the body, the stiff dorsal hairs materially assisting progress. The speed is probably more rapid than that of any other known genus of the Scarabaeidae occurring in the United States. Indeed, it progresses on its back at about the same rate as the hairy caterpillars do on their legs and prolegs, and in a similar manner.

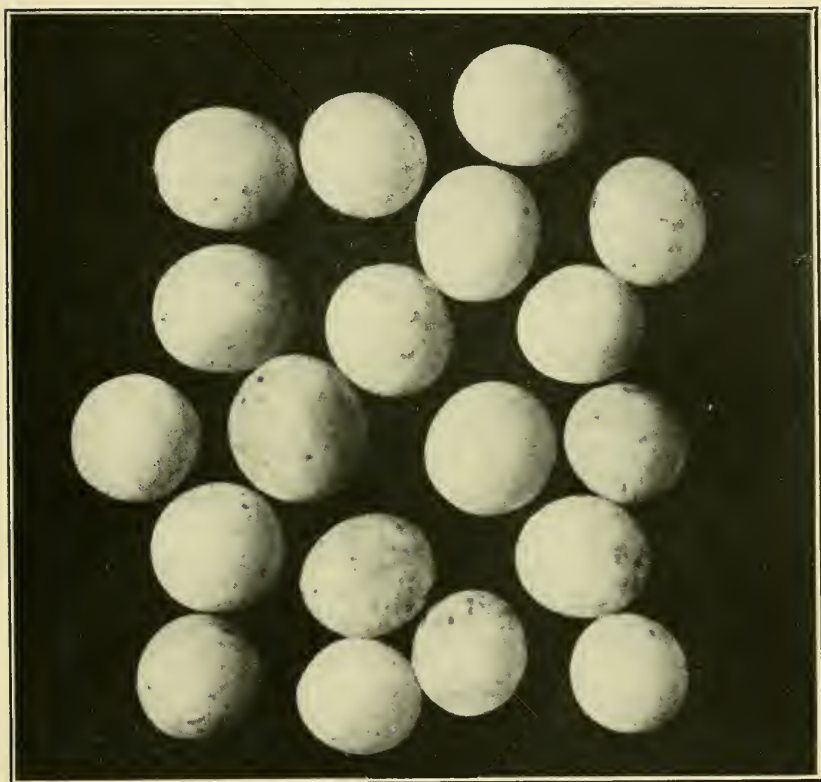


FIG. 3.—True white grub (*Phyllophaga* sp.) which does not crawl on its back. Enlarged. Compare with figure 2.

TECHNICAL DESCRIPTION.

THE BEETLE.

The beetle of *Cotinis nitida* is related, although rather distantly, to the brown May or June beetles of the North, belonging to a different group of the Scarabaeidae—the Cetoniini. The appearance is quite different. It is variable as to color, but is usually a beautiful velvety



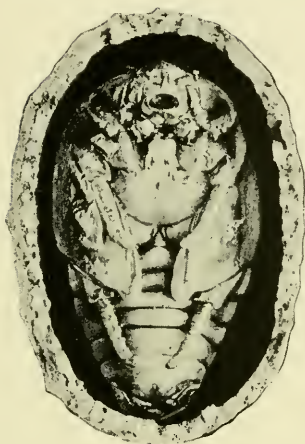
GREEN JUNE BEETLE.

Eggs, highly magnified.



GREEN JUNE BEETLE.

Full-grown larvæ of green June beetle (*Cotinis nitida*), actual size.



A



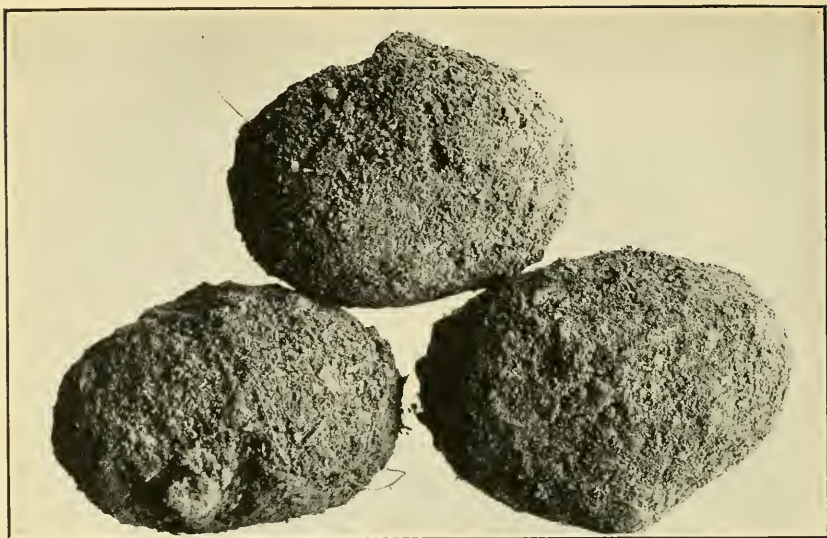
B



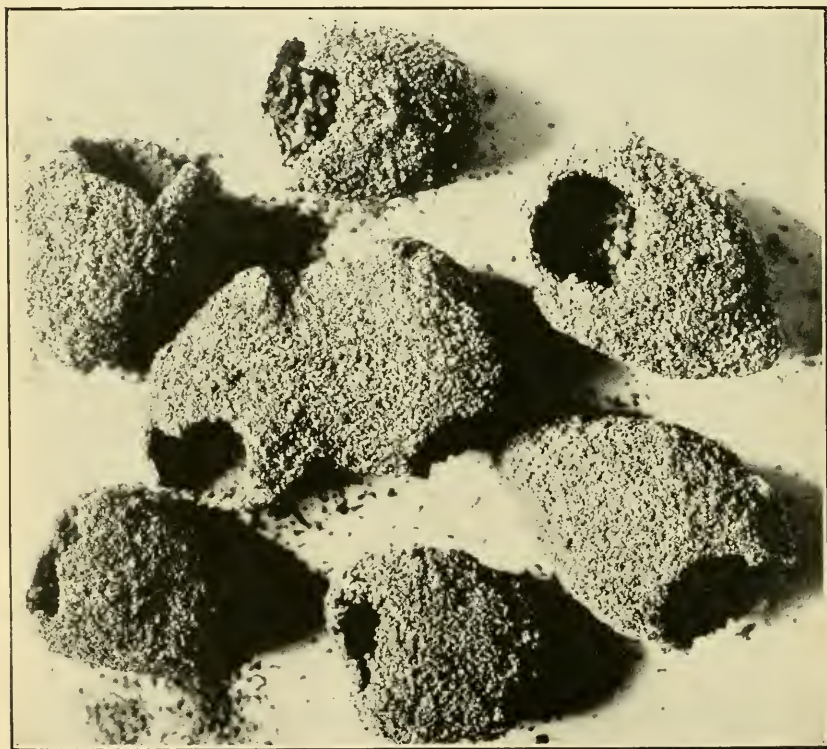
C

GREEN JUNE BEETLE.

A, pupal cell opened to show pupa within; B, pupa removed from cell, showing more details of structure.
C, pupa of a white grub (*Phyllophaga* sp.).



A



B

GREEN JUNE BEETLE.

A, Pupal cells; B, same showing exit holes of beetle. About natural size.

green on the dorsal surface, with the margins orange yellow, this latter color frequently extending to other portions of the elytra or wing-covers. The ventral or lower surface is shining green and orange yellow. The thorax is subtriangular and the head is armed with a horn-like process or clypeal horn which is more prominent in the male. The shape and size of this clypeal horn vary. The length of the beetle is from three-fourths of an inch to one inch in the larger individuals.

The average size is much smaller than that of the related species, *Cotinis mutabilis* Gory,⁴ and there are other points of difference, the most striking being the uniform metallic green color of the lower surface of the latter and the larger clypeal horn.

THE EGG.

The egg (Pl. I) when first deposited is gray or dull white, oval in outline, and measures about 1.5 millimeters. Within a day or two after deposition the egg becomes perfectly spherical and larger in size, measuring nearly 3 millimeters in diameter. This enlargement of the egg, as has been observed in other related scarabaeid genera, e. g., in *Euphoria*, is obviously due to the development of the embryo within by the absorption of moisture from the soil.

The egg is perfectly smooth and rebounds or bounces like a rubber ball when struck on a hard surface. Several days after deposition the embryonic outline of the larva begins to take definite shape, as viewed through the thin, transparent eggshell. Finally, when the larva is hatched, what remains of the original eggshell is a mere vestige of thin, transparent tissue.

Mr. J. E. L. Lauderdale, while employed on truck crop insect investigations at Baton Rouge, La., in August, 1916, observed that each egg was inclosed in a small ball of dirt about one-fourth inch in diameter, and that some of these balls, as many as 15 or 20, occurred together. All of the eggs had been placed by the female in the dirt in the bottom of the cage in which they were confined.

THE LARVA.

FIRST STAGE.

The larva when first hatched measures 6 to 6.5 mm. in length and 2 mm. in width. The body is cream white and of uniform width; the head is yellowish white, soon turning to light brown, later becoming dark brown at its widest part, measuring 1.18 mm. The dorsal surface of the body is clothed with

⁴ A large series of specimens of these two species from many localities show such variation as to lead to the belief that *mutabilis* Gory might be merely a race of *nitida* L., but careful study has convinced the senior writer that they are distinct.

minute stiff hairs in transverse rows, becoming elongated toward the caudal extremity.

SECOND STAGE.

After the first molt the larva measures 15 to 17 mm. ($\frac{3}{4}$ inch) long, and 4 to 5 mm. wide, or nearly three times the size of the newly-hatched larva. The color has changed slightly to light grayish, but apparently there is no other change in general appearance. The head measures across the widest part 2.21 mm.

THIRD STAGE.

After the second molt the larva measures 28 mm. (over a full inch) in length, and 6 to 7 mm. ($\frac{5}{16}$ inch) wide. The hairs on the dorsal surface of the body are more prominent and bristle-like.

THE FULL-GROWN LARVA.

The larva, when full grown, measures from 45 to 48 mm. (2 inches) long and 11 to 12 mm. ($\frac{1}{2}$ inch) wide. Before transforming to the pupa the head measures 4.14 mm.

Full grown larva.—Length, 40 millimeters, somewhat largest posteriorly, subcylindrical, broader at thorax and eighth and ninth abdominal segments, which are materially swollen. More flattened ventrally, with a distinct swollen lateral ridge just below the stigmata, which rather increases the flattened aspect of the venter. General color, glassy yellowish white, inclining to green or blue toward the extremity. Head, rather small, flattened, well inserted into the prothoracic segment, chestnut brown in color. Dorsal surface of the body strongly transversely corrugate or wrinkled, each of the chief segments having three distinct ridges, the whole body studded with short, thick yellowish bristles, which are most dense on the dorsal ridges and more sparse, but longer, on the ventral and anal segments. Dorsally these stiff hairs are directed posteriorly and materially assist in the dorsal locomotion. The legs are honey yellow, covered with similar stiff bristles without definite tarsal claw. They are short compared with the larvæ of *Lachnosterna* generally. Prothoracic segment with a honey yellow horny plate in front of the spiracle, which, as usual, is rather larger than the abdominal spiracles. Mandibles short, stout, dark brown, with the left (looking from the dorsum) 4-dentate and the right 3-dentate. Antennæ short, 4-jointed, joints subequal in length, diminishing in width, from 1 to 4. maxillary palpi, 3-jointed, joints subequal in length, terminal narrowest at tip. Labial palpi, 2-jointed, joint 1 longest, somewhat swollen at tip and bearing a short pointed joint 2, on the inner side of its tip. Labium covered with short stout bristles. Maxillæ with long, stiff bristles on the inner surface and with two long, sharp, black teeth near the tip.

The description of the full-grown larva is taken from Riley (20).

THE PUPAL CELL.

When the larva has attained full growth it transforms to the next or pupal stage in a substantial oval cocoon or cell (Pl. III, A; Pl. IV) constructed of earth composed of particles fastened together by a viscid fluid excreted by the larva. At this time the larva loses considerable size by the excretion of the fluid, a habit common to many

forms of beetles. While the outer surface of this cocoon-like cell is rough, the interior is smooth and suggestive of a bird's egg. There is a protuberant area on one side, presumably on the lower surface, which may be due to the excess of fluid voided by the larva while constructing its cell.

This cell measures about $\frac{7}{8}$ inch or 16 mm. in length and $\frac{5}{8}$ inch or 12 mm. in width.

THE PUPA.

The pupa bears some resemblance to the adult or beetle and is white when first formed, changing to light or yellowish brown, afterwards becoming gradually darker, and just before emergence it takes on some of the metallic green and brownish tints of the adult.

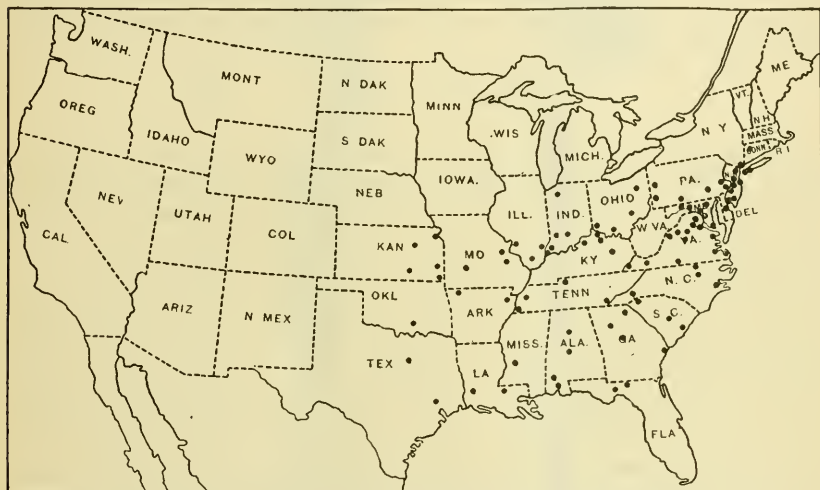


FIG. 4.—Distribution of green June beetle in the United States.

It measures about 1 inch in length and half an inch in width. Other characters are shown in Plate III, B.

DISTRIBUTION AND INJURIOUS OCCURRENCE.

The green June beetle (*Cotinis nitida*) has a wide distribution in the eastern portion of the United States. (Fig. 4.) On the Atlantic coast it ranges from the southern portion of New York State to Florida and Texas in the South, and it is found also in the southern portions of Connecticut, Pennsylvania, Ohio, Indiana, and Illinois. The species continues southward through Missouri, Kentucky, and Oklahoma, and probably the remaining southern States, from which source, however, there are few records available.⁵ There is a single

⁵ The nearest related species, *C. mutabilis* Gory, occurs abundantly in the arid and semi-arid regions of the Southwest.

record of the identification of the larva from Holyoke, Mass., a locality not shown in the map.

Although the green June beetle has a considerable range, its natural preference for a rich soil, either sandy or loam, renders it important economically in the southern trucking regions. The sandy coast region affords ample opportunity for the increase of this species in trucking regions, and for the same reason it has been able to obtain a foothold in the vegetable-growing sections of Long Island. Indeed, it is evident that the cutting down of forest growth for the settlement and cultivation of the trucking regions of tidewater Virginia and Long Island has been the means of affording the green June beetle ideal conditions for its multiplication. The accumulation of humus following the destruction of the forests and the abundant manuring of these tracts furnish the requisite amount of food for the development of the insect.

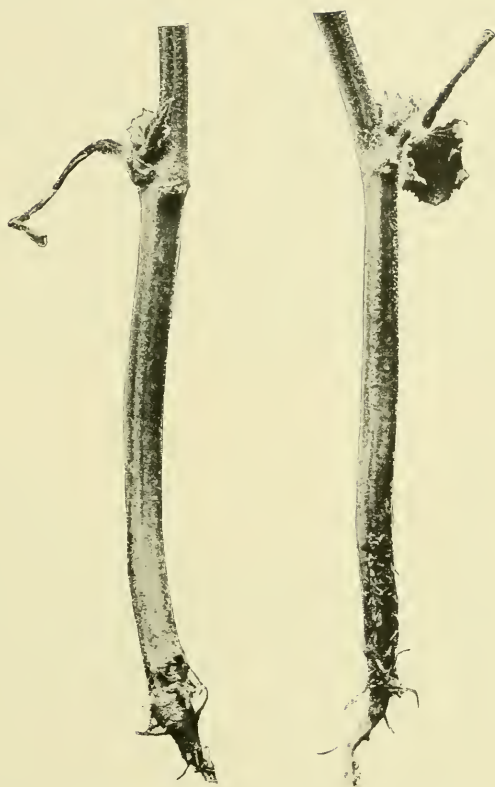
NATURE OF INJURY.

For upward of a half century the green June beetle has been known to entomologists of this country, and its economic status has frequently been discussed. From the literature on this subject it is evident that the majority of our entomologists concede it to be an occasional pest, and that locally, at least, it becomes seriously injurious. None, however, had given this insect very careful study, particularly in regard to the feeding habits of the larva, until the past few years. Since about four-fifths of the life cycle of the insect is passed in the larval form, it is in this stage that the most serious injury is accomplished. Frequent mention is made of this insect as injurious in the parent or adult form, but it has received comparatively little notice as being injurious in the larval state. Recent reports and observations indicate a reversal of conditions, since it has been reported more frequently injurious in the larval or grub stage. Indeed, many such reports are received by the Department of Agriculture every year.

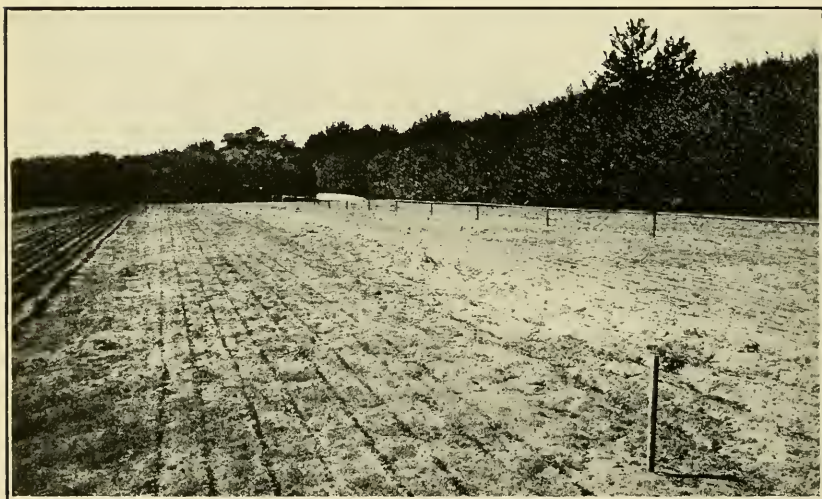
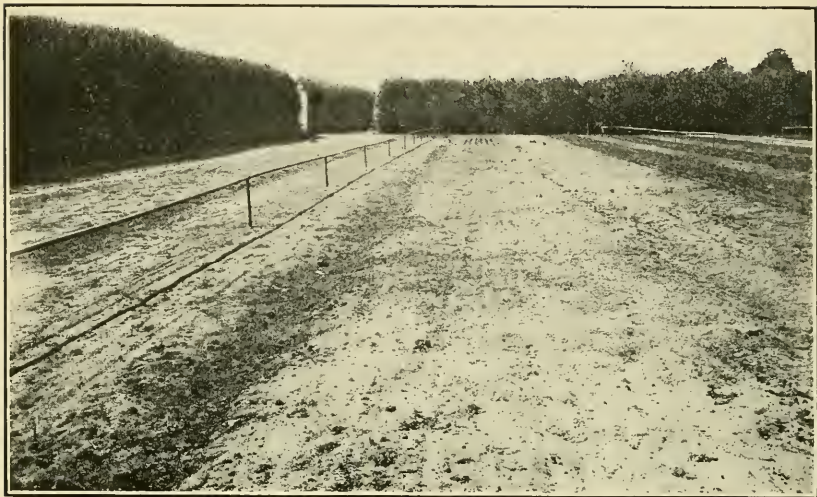
Its habit of breeding in rich loam or rich, more or less sandy soil renders it, at least locally, a serious pest to trucking industries not only of the southern States but also in the East and westward to the Mississippi Valley.

In tidewater Virginia the larva of this insect has done considerable damage intermittently for a number of years. With a view to determining a method for its control in that region a study of its life history and habits was begun there in the fall of 1913.

While the larvæ feed normally and largely on soil rich in humus or organic matter and on manures, rootlets of succulent plants and other vegetable matter on the surface of the ground doubtless formed a part of the insect's natural food before it had acquired the habit of

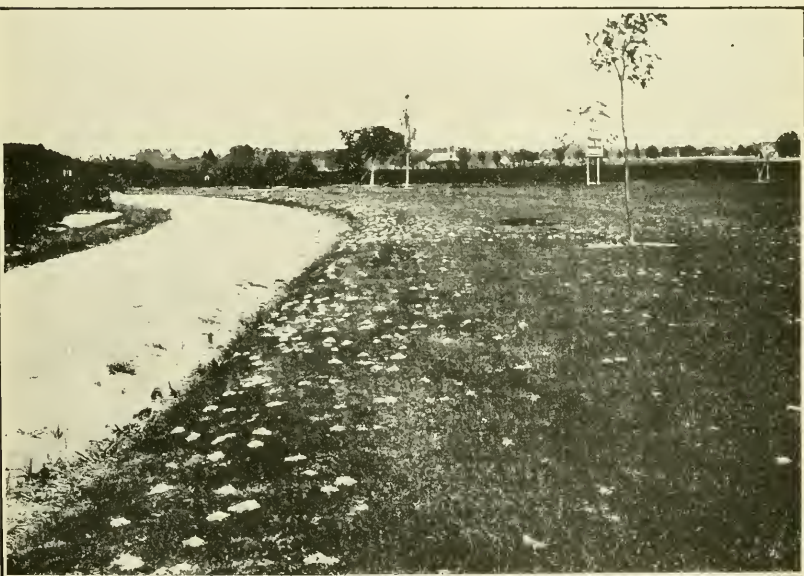
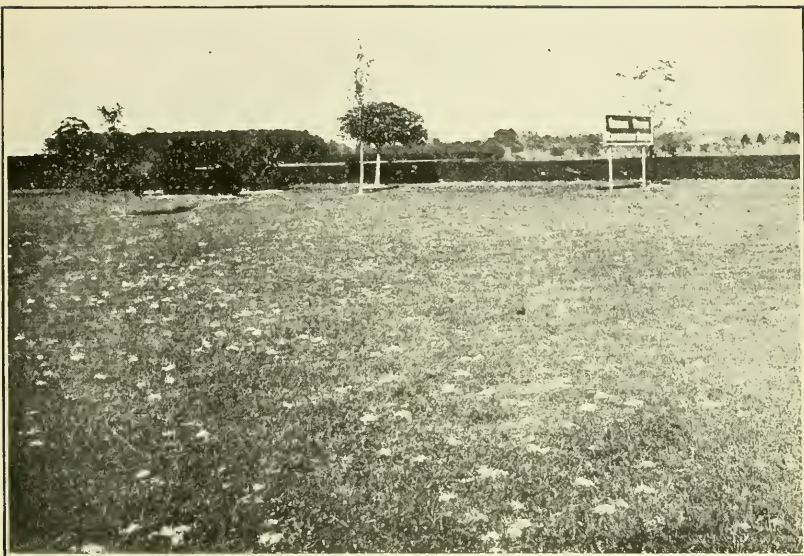


CUCUMBER PLANTS SHOWING ROOT AND STEM
INJURY BY LARVÆ OF GREEN JUNE BEETLE.



VIEWS OF PARSLEY FIELD INJURED BY LARVÆ OF GREEN JUNE BEETLE.

The upper field was re-sown twice, the lower field three times.



WORK OF LARVÆ OF GREEN JUNE BEETLE ON LAWN AT NORFOLK, VA.

injuring vegetable and other crops. The female beetles are strongly attracted to humus, decaying plants, and manure for the deposition of their eggs, but the larvæ or grubs are often directly injurious to plant life by chewing tender seedlings, stems, and rootlets, e. g., as shown in Plate V, which illustrates injury to the root and stem of cucumber. This chewing may be continued until the roots or tender stalks become partially, if not completely, severed. The principal injury, however, is due to the work of the grubs in the soil, where they cause around the growing plants an upheaval, which disturbs the root system mainly by depriving it of necessary moisture. Their constant burrowing and tunneling under the earth in fields and gardens also loosens the surface soil, causing it to dry out and become porous, and retards the growth of shallow-rooted plants in much the same manner. Where larvæ as well as beetles are unusually abundant, a similar effect is produced by the perforations which they make in emerging and again in reentering the soil. (Pl. VI.) Many instances of this nature are known and are here cited.

An extreme form of injury recorded by Riley (20) is to the effect that in the case of injury to celery the heart of the plant became choked with soil thrown up by the larvæ, and the acid excrement of the larvæ induced rot.

Injury to lawns and putting greens is due, in the main, to the little mounds of earth which the grubs leave on the surface of the soil, and on the grass itself. These mounds not only disfigure the lawns and greens but, in the case of the latter, which should be kept smooth, they often deflect the golf ball. Here, also, the burrowing and tunneling, as in the case of attack to cultivated fields, cause the grass to suffer from lack of moisture. Plate VII illustrates how lawns may be disfigured by these mounds, which show plainly on the grass.

INJURY BY THE GRUBS TO LAWNS AND CEREAL AND FORAGE CROPS.

During September, 1902, Mr. E. M. Talcott reported injury by this grub on the golf links of the Washington Golf Club at Rosslyn, Va. The grubs were extremely abundant in that vicinity. They crawled to the surface of the ground at night, and caused injury to the grass by boring short distances just beneath the surface, throwing out small amounts of earth, and making little hummocks of sufficient size to deflect the golf balls and thereby cause considerable annoyance.

October 1, 1903, Mr. F. W. Barclay, Haverford, Pa., sent mature grubs with the statement that they did very considerable damage to the greens and turf of the Merion Golf Club at that place. The grubs were present in large numbers over an area of about 50 acres, and seriously injured the turf, nearly ruining the putting greens. It could not be noticed that the grubs ate the roots of old or growing

grass, but if freshly cut grass were placed in piles, say 1 foot deep on the soil, the grubs would come up and enter into the piles within a few hours. Wasps⁶ had learned to search for the grubs in these piles of grass. The specimens sent had been caught after they had entered new grass piles. This suggests that after the insects have been seen to enter the piles they could be killed there by hand methods.

In 1904, Mr. Barclay sent, May 28, a photograph showing the actual damage done to the golf links at Haverford. June 6, Mr. Samuel P. Hinckley, Lawrence, Long Island, N. Y., stated that on his tennis grounds little hills of sand, like ant hills, were thrown up and that by running a hooked wire down into them the white grub could be pulled out.

At Louisville, Ky., special work was conducted by Mr. J. J. Davis on this species. Injuries were observed and reported by him to the golf grounds of the Louisville Country Club. Here the grubs were not directly injurious to the grass, but worked in the putting greens during the night, throwing up little hills of earth. If these were not swept off early in the morning they would be trampled on by the players, thus packing a thin layer of earth over the surrounding grass, killing the grass in these particular spots, and roughening the green, which should be perfectly smooth. At no time were the grubs observed actually feeding on the roots of the grass, and there was no evidence of injury to the grass other than the indirect injury noted. The entire golf course was plowed and seeded in 1909, and the first occurrence of the beetles was in 1911. Each year the ground was heavily fertilized with animal fertilizers, principally sheep manure.

March 6, 1915, Mr. Wm. Buck, Waterloo, Ill., described these larvæ as crawling on their backs and working after sunset and during the night. He stated that they worked underground and that they ate the roots of plants. The grubs worked their way to the surface and collected under pieces of manure, and in their movement upward uprooted and exposed the roots of young alfalfa plants. Their burrowing also made the soil porous and spongy, a condition which accelerates evaporation and has a damaging effect on the plants. Injury was confined entirely to the young plants, those with even a moderately developed root system not being injured. No evidence was found that the grubs actually gnawed the roots.

October 27, 1915, this species was observed in abundance by Mr. A. L. Chapman, Washington, D. C., who stated that grubs of this June beetle had been eating the small terminal roots of grass, chiefly Capitol lawn and crabgrass, practically ruining the entire lawn. Previous attacks had been noticed, but none as severe as this. On three occasions a pint or more of the grubs was taken from the cement floor

⁶ "Control by natural agencies," p. 31.

of the areaway leading into the basement. The grubs were most numerous and active on warm, humid nights, especially after rains. The lawn was about 50 by 50 feet, raised about 4 feet from the level of the street, and was kept constantly supplied with water by two hydrants. The grass presented a yellowish brown hue instead of a grass green, showing lack of proper nourishment.

Other instances of injury to lawns and golf links have been reported, but will receive no mention here.

In rearing cages the grubs cut off young stalks of wheat, rye, cotton, sorghum, and paspalum grass (*Paspalum dilatatum*) but did not attack other grasses or corn which were grown in these cages.

INJURY BY THE GRUBS TO VEGETABLE AND GARDEN PLANTS.

Practically all cases of injury mentioned below were accompanied by living specimens of the larvæ of the green June beetle.

February 4, 1901, Mr. S. J. Trepess wrote that the larvæ occurred in large numbers at Glen Cove, Long Island, especially where there was mulching. There were large patches in lawns where the larvæ had entirely killed the grass. He reported that four large beds of geraniums were destroyed, that they ate the epidermis off the plants at the surface of the ground, destroyed strawberry plants set out from pots in September, and attacked roots and crowns, so that every day plants were seen to wilt. Injured plants were replanted about the beginning of October on land where no trace of the insects was visible. Each plant was usually attacked by from two to six larvæ. The soil contained much humus, which our correspondent recognized as the cause of the larvæ being so numerous and thriving. Mr. Trepess had been bothered with these insects in his lettuce and violet frames for two years, and had caught many of them in tomato cans sunk in the ground, the top of the can being about half an inch lower than the surface. February 5, Hon. J. H. Bromwell, Cincinnati, Ohio, sent nearly mature larvæ of this species, with statement that it was acting like a cutworm in working around the stalks of celery and other plants and actually cutting them off close to the ground.

June 11, 1904, Mr. Moritz E. Ruther, Holyoke, Mass., sent specimens about one-third grown, stating that they were feeding on beans, beets, lettuce, potatoes, tomatoes, carrots, dahlias, roses, and other plants, nipping the young plants just underneath the crown, and afterwards pulling the leaves into the earth.⁷ The trouble was described as having begun about three years previously and attack was first confined to lettuce and beets; later they were described as attacking

⁷ Unfortunately, a common cutworm was involved in this attack, and it is not known positively that the grubs were responsible for the entire injury.

everything grown. Chickens were stated to have refused to eat the grubs.

August 19, 1904, Mr. Henry Chapman, Saltville, Va., sent half-grown larvæ, stating that they were very abundant in celery and strawberry beds. A dozen of varying sizes were found near one strawberry plant that day. The smaller grubs which had hatched from eggs recently deposited by the beetles remained near the surface, while the larger ones occurred farther below. The grubs were not seen to injure the celery until it was put in the ground in the winter, when a good-sized stalk was observed "eaten through." Strawberry plants were destroyed in the midst of a host of these pests. On September 14 specimens in different stages of growth were found 4 to 5 inches below the earth's surface. The beetles were numerous in that vicinity during July. They were observed depositing eggs and soon afterwards larvæ were noted developing rapidly.

October 23, 1907, Mr. Barclay wrote that since 1903, when the Bureau of Entomology had correspondence with him in regard to the occurrence of this insect at Haverford, Pa., it had not appeared at all in 1904, 1905, or 1906. October 26, Mr. P. Haupt, New Athens, Ill., reported that his vegetable and flower garden and a portion of his lawn were very badly infested. Because of the great numbers of the grubs, especially in the vegetable garden, it was feared that great damage might be done the next spring. Lettuce which had been sown several weeks before was undermined so badly when an inch high that the plants died from drought, the grubs having worked around the roots so much that the soil had become as fine and loose as dust. The grubs also ate off the leaves and gnawed the tips of hyacinth bulbs. The presence of the insects in the vegetable garden was attributed to the use of horse manure from the stable.

November 16, 1909, Mr. E. G. Smyth reported the following observations on this species from Churchland, Va.:

The hard ground between frames of young cabbage is "pepper-boxed" with holes made by these larvæ in entering the ground. The grower believes that they come to the surface during the night to obtain moisture, and reenter the soil before daylight. It is evident that they come forth to feed; but as they can not possibly get into the frames of young cabbage, and as there is very little vegetation outside of the frames, it is a question what they find to eat. Plainly none had gained entrance to the frames, for the soil within had none of their holes at the surface. Once inside, they could play consummate havoc with the tender cabbage seedlings. In the preceding spring, beets had been grown in these cold frames, and something working under the ground, presumably the same larvæ, did considerable damage to the plants. During the intervening summer months the frames were in disuse, so only weeds grew in or between them. Before planting the cabbage in the frames the old soil had been replaced by fresh soil from elsewhere, which accounts for there being no grubs in the frames at this time.

October 8, 1912, James Kenny & Co., Riverside, N. J., wrote relative to this grub as follows:

It is cutting the lawn around here every night, and also cuts the roots of geraniums and other flowers.

January 11, 1913, Mr. E. B. Cantrell, Winston-Salem, N. C., reported that the grubs were very abundant in his garden; so much so as to interfere with the growth of the plants. The two years previous Mr. Cantrell used stable manure freely on his garden and, as he surmised, this was doubtless responsible for the appearance of the grubs in such numbers. Writing March 18, Mr. Cantrell said:

I have observed the grubs for a number of years and have never known them to occur on any kind of land or injure any kind of crops excepting where stable or lot manure had been used. Therefore their greatest numbers are to be found in gardens. The grubs breed and thrive on manure and almost any crops planted there. Especially in dry weather there is damage by them as they plow up and make holes that cause plants to suffer for moisture. Sometimes plants are cut off, tomatoes on the ground eaten, and especially have they injured my celery.

May 17, 1914, Mr. Edward T. Knight, Bureau of Plant Industry, reported injury by this grub to iris, which had been a source of complaint about a year before.

October 24, 1914, Mr. C. F. Turner, Bureau of Entomology, found the grubs doing considerable damage in the gardens belonging to Mr. L. G. Buckner at Memphis, Tenn. Corn, potatoes, turnips, and eggplant were said to be attacked. Mr. Buckner wrote November 5, 1914:

The grubs in our garden keep the ground near the surface pulverized. A rain, of course, packs the ground and in a day or two the ground is again pulverized. We are not sure that the plants died because the roots were eaten or whether it was the continuous working under and around them. They did not bother the plants on top of the ground. We had a very fine patch of turnips and they killed nearly all of them. They also ruined tomato vines and English peas. They attacked fall potatoes, not killing the vines, but I know they ate some of the potatoes; however, not a great deal. Our garden has been well fertilized with stable manure.

During the same month Prof. James Troop, entomologist at Purdue Experiment Station, received specimens from a correspondent at Bedford, Ind., who reported that the larvæ damaged endive. The correspondent wrote October 27, 1914, as follows:

The endive I have covered with a board to bleach. Frequently when I would lift a board off of the endive I would see the worm disappearing in the hole out of which his head had been protruding, and quite often they would in this manner eat a third and often half of the bunch of endives.

The correspondent had adopted two methods for bleaching the endive—laying boards over the plants and bunching and tying up the heads—but the grubs attacked only that under the boards.

December 17, 1914, Mr. A. Patterson, Ensley, Ala., wrote that these "grub worms" keep the soil in the garden very loose, especially around the roots of collards and turnips. They were unevenly distributed in the garden, in 5 or 6 foot areas in holes 4 or 5 inches apart. The surface of parsnips was eaten off in places, some eroded areas extending completely around the root and stopping its growth.

Mr. Thomas H. Jones, Bureau of Entomology, has contributed the following notes, based on specimens:

November 22, 1915, Mr. J. O. Bethes, Franklinton, La., wrote in substance:

This grub was taken from a garden here where the species is doing a great deal of damage. In the daytime the worm penetrates the earth to a depth of about a foot and at night comes to the surface and works up the ground in the manner of a mole. It is doing damage to turnips, cabbage, and other plants growing in the gardens this season of the year.

December 28, 1916, Mr. Jones observed the larvæ in water in a ditch at the Louisiana State University, Baton Rouge, La. Although they were motionless when removed they soon became active when brought into the office. They had evidently bred on the parade grounds on the other side of a walk separating the grounds from the campus, since the beetles had been observed in large numbers in late summer. Numerous trails were found in the wet dirt, and there were holes and piles of freshly worked-over dirt in the grassland. The heavy rains caused the grubs to come to the surface. Prof. O. W. Rosewall had previously seen the grubs above the surface at night after heavy rains.

March 16, 1917, Mr. W. J. Sutcliff, Monroe, La., wrote:

A while back these grubs were in the garden by the millions, and yesterday a number were found dead. They, or some other insect, literally plowed the very top of the ground up, and by doing so they killed the little plants coming up. Digging down below the surface of the ground for three or four inches, the ground is perforated with holes resembling on a small scale those made by crayfish.

October 28, 1918, Mrs. A. M. Kistler, Morganton, N. C., sent specimens of larvæ with the statement that she could furnish them by the bushel, and that they were infesting her garden and hotbed. They were described as destroying everything in the garden—cabbage, turnips, salsify, lettuce, radishes, peppers, tomatoes, and celery. Paris green was tried without effect, and kerosene emulsion was advised.

November 13, 1919, Mr. C. S. Stewart, Baton Rouge, La., reported the grubs of this species in his garden. He wrote:

For the past six years my fall garden has been ruined almost entirely from this cause. It is a grub that grows about 1 inch long, comes to the surface during the night, runs on its back, eats almost everything green, and to give you an idea of their numbers I will say that I have picked up as many as 1,000 in a single night. Where they work and crawl the surface of the ground

looks as if it had been raked. I use stable manure, but within two years have limed the soil. Right now I am plowing out my grub crop, turn the soil, pick up, and throw to the chickens. I haven't anything in my garden this fall except grub worms.

INJURY BY THE GRUBS IN A GREENHOUSE.

A single instance of injury by the grubs of this species in greenhouses was reported in November, 1898. Mr. W. E. Pray, Kinkora, N. J., reported injury in his violet houses (31). The larvæ were first noticed soon after the plants had been put in the bed, and at this time they seemed to do little if any harm, but the ground was described as being "kept well cultivated for 2 inches deep by their movements." As the plants grew, the larvæ, it is stated, began to feed upon the fibrous roots, and were so doing at the time of writing. They were also said to devour the outside petals of the flowers which rested upon the ground and frequently ate into the hearts of the flowers, rendering them unfit for shipment. Specimens of violets showing the reported injury were received with the grubs. A great number of the flowers were described as having been destroyed. It was believed at the time that cutworms might be the real culprits, but no definite conclusions could be reached.

In this connection it should be noted that the grubs are frequently brought into greenhouses with manure, and as a consequence of the superheated indoor atmosphere the beetles issue practically throughout the winter, as has happened at Norfolk, Va., and at Washington, D. C.

INJURY BY THE BEETLES.

Attention has been drawn to the injurious attack of the beetles to fruits. Of these, the thin-skinned fruits, especially figs, peaches, and grapes, are most often damaged, other fruits which have been listed being occasionally or slightly attacked. Injury to figs in South Carolina, Georgia, and other southern States is an annual occurrence, and indeed one of the popular names of this beetle is "fig-eater." From Pennsylvania southward come frequent reports of injury to peaches, often to those which are quite sound, contrary to the opinion of some authors that only decaying, partially decayed, or overripe fruit is attacked. The green June beetle is a very well-known grape pest, and Prof. H. Garman (32) reported injuries to this fruit in Kentucky as follows:

The common green June bug, well known to every Kentucky school boy, becomes very troublesome locally and occasionally by cutting the skins of grapes and utterly destroying the fruit of whole bunches and even whole vines. On the experiment farm at Lexington this pest would, if allowed to work unhindered, destroy the whole crop of the early varieties in the experimental vineyard. It was formerly more troublesome than now, but is liable any season

to appear in such numbers as to be the cause of anxiety on the part of those having the vineyard in charge. The very sweet, thin skinned, early sorts suffer most severely. On a visit to the vineyard, August 1, 1896, I found Moore's Early, Poughkeepsie, and White Imperial being severely damaged, while Brilliant was only moderately injured. The clumsy beetles were clinging to the berries, in some cases a dozen on a bunch, greedily devouring the pulp and leaving them in an unsightly and utterly ruined condition. They were guilty during the same month of injury to early peaches and plums.

Webster and Mally (27) have reported injury by the beetles to tomatoes in southern Ohio, and state that melons are sometimes eaten; corn in the ear is a favorite food, and not infrequently the beetles are sufficiently numerous to injure noticeably both field and sweet corn. They have even been observed injuring young corn plants by gnawing into the stalk, and in one instance young sorghum plants were attacked.

The beetles are also frequently complained of as a nuisance in well-kept lawns and golf greens, because of the little mounds of earth excavated by them as they enter the ground, but they are by no means as troublesome in this respect as are the larvæ.

In 1909 Mr. R. A. Vickery, Bureau of Entomology, observed the beetles at Salisbury, N. C., August 10, feeding on kernels of corn near the tip of the ear, the injury having first been started by the related *Euphoria sepulchralis* Fab. At Wellington, Kans., Messrs. E. O. G. Kelley and T. H. Parks, Bureau of Entomology, observed beetles feeding on young stalks of corn July 19. They were boring large holes near the base of the stalk between the second and third joints. Mr. Kelley repeated this observation and later, August 10, 1911, found them feeding on corn kernels. July 14 of the same year Mr. G. G. Ainslie, Bureau of Entomology, observed the beetles feeding on sweet-corn kernels at Nashville, Tenn.

At the same locality Mr. W. H. Larrimer, Bureau of Entomology, reported injury to sorghum July 21, 1913. The beetles were observed in the "throat" of the plants, evidently having been attracted by the honeydew of the corn leaf-aphis,⁸ or by the sweet sap of the sorghum itself. This attack caused the leaves to split at the base, injuring the plants to quite an extent. When the field was revisited a week later the beetles had disappeared, and while the plants were attempting to outgrow the injury, the damaged ones were easily distinguished.

July 9, 1915, adults were observed at Ocean View, Va., flying over lawns and hedges and flower beds, those captured proving to be largely females. Later in the month they were also observed at Portsmouth, Va. The parasitic sarcophagid flies were observed on hedges, and in all probability thus able to deposit their larvæ on the adults of *C. nitida*, resting on the hedges.

⁸ *Aphis maidis* Fitch.

June 29, 1916, a single adult was captured at Norfolk, Va. By July 10 numbers were observed flying around hedges and lawns.

By August 8 the beetles were observed at Portsmouth, Va., in large numbers. They disappeared about September 20. In 1916 Mr. J. E. L. Lauderdale observed adults at Baton Rouge, La., feeding on the juices of corn. They were observed between July 8 and September 19, none being found after September 22, occurring in greatest numbers in August. On August 4 Mr. F. B. Milliken, Bureau of Entomology, observed the beetles at Wichita, Kans., feeding on egg-plant in the early morning, making large ragged cavities in the sides of the main stems or branches.

During the next five years, up to 1922, few complaints of injury were received aside from the normal number to lawns and golf links, these emanating from Maryland, Virginia, District of Columbia, southern Pennsylvania, and New York. Injury to celery and endive, resulting in a loss of more than 40 per cent of the crop which might have been due to this insect, was reported at Sunbury, Pa., but without specimens. Complaints of injury in gardens were received from Louisiana in 1919, one correspondent at Amite stating that for six years his garden had been almost ruined from this cause.

BEETLES ENTERING BEEHIVES.

During July, 1903, the senior author's attention was called to great numbers of dead beetles of *Cotinis nitida*, found under the entrances to beehives on the grounds of the Department of Agriculture, where the living beetles were quite a nuisance. There were considerable numbers of them endeavoring to obtain entrance to the hives, and they occupied the attention of a number of the bees that were as intent on preventing their entrance as the beetles were on getting into the hives. On account of the hard exterior coating of this insect the bees' stings did not appear to penetrate until perhaps after a great many attempts. The beetles were persistent, but very slow and sluggish, and under the circumstances it can readily be imagined that an appreciable amount of honey that might have been produced was lost through the distraction of the attention of the bees to the intruders. The beetles appeared to be utterly unaware of their danger and as stupid as the Scarabaeidae are generally accredited with being, at least when not in flight.

LIFE HISTORY AND HABITS.

In the vicinity of Norfolk, Va., the beetles make their first appearance about the middle of June, reaching their height in numbers by the middle of July and continuing numerous until the middle of August, disappearing about the first week in September.

Throughout a period of from 4 to 6 weeks the beetles occur abundantly, being most active late in the afternoon, when they fly either close to the ground or soar high among the tree tops. When they alight on trees serious injury sometimes results from the beetles gnawing into the young twigs, causing the latter to break off. The beetles are also attracted to ripe fruit and gather by dozens on ripe melons, tomatoes, and green corn.

Mating occurs during periods of rest, when the beetles alight on tree tops, shrubbery, fences, or on lawns and grassy places, the females attracting the males—sometimes many males attending one female. Before oviposition the females, buzzing like bees, fly close to the ground and select a place to enter the soil. After alighting they disappear rapidly from the surface and remain in the ground for two days at a time, sometimes coming to the surface to feed and again disappearing.

EGG LAYING.

The soil condition that attracts the parent beetles for egg laying is land originally sandy, subsequently richly incorporated with humus or organic matter, either in the form of well-rotted manure or decomposing vegetation. Such are the field conditions of the two principal infested localities in the vicinity of Norfolk, Va., where the green June beetle occurs in abundance. This gives a soft, warm, mellow soil, rich in organic food, retaining moisture, yet never soggy or cold during the egg-laying period, and affords easy access for the beetles to enter and deposit eggs. The conditions are ideal for incubation and the subsequent work of the larvæ. Cage experiments demonstrated that a pure sandy soil does not attract the beetles to oviposit, but when well-rotted manure is added in about equal portions the beetles readily deposit their eggs.⁹

The reported finding of larvæ in dung has often raised the question as to whether eggs are deposited in manure. There are instances on record where larvæ have been so found, and the larvæ have received the local name of "dung grubs." Mr. F. Richardson, of Portsmouth, Va., states that about 1908, when he first began hauling cow manure on his farm, he often noticed that hardened or caked pieces of dung when broken revealed the presence of numerous "grub worms," of what he supposed to be this insect. Several years after the use of this manure his place became noticeably infested with the grubs, so that he finally discontinued the use of this manure and supplanted it with stable manure. During the height of their season the beetles were often observed entering and issuing from the soil in the process of

⁹ The beetles were induced to lay in pure sand, although reluctantly, and with much effort on the part of the female to escape confinement and to search through the sand for a suitable spot for deposition.

egg-laying. This matter of the dung-feeding habit will be discussed further under the heading "History and literature," p. 28.

PERIOD OF INCUBATION.

The period of incubation in the field, as will readily be understood, depends in a large measure on climatic conditions for that period, and moisture particularly plays a part in the development of the embryonic larva. This fact has been illustrated with eggs kept in the laboratory in vials. It was determined that the eggs when first deposited are small in size, but with suitable moisture conditions finally become larger and assume the spherical shape, the larvæ hatching within a period varying from 12 to 14 days. Eggs kept in vials in which the sand is allowed to become dry remain small and will not develop until suitable conditions of moisture occur. The incubation period is then very much prolonged, and the resulting larvæ are not so vigorous and are somewhat smaller than the average. Usually the normal period is from 10 to 15 days. The depth at which the eggs are deposited in the field provides a temperature nearly uniform, and even during dry weather the moisture content of the soil at a depth of from 6 to 8 inches can be but slightly affected. The length of the incubation period, as observed in eight instances, is given in Table I.

TABLE I.—*Incubation period of Cotinis nitida.*

No.	Date of deposition of eggs.	Date of hatching of larvæ.	Incubation period (days).
1.....	Aug. 5	Aug. 17	12
2.....	Aug. 14	Aug. 23	9
3.....	Aug. 16	Aug. 30	14
4.....	Aug. 21	Sept. 3	13
5.....	Aug. 23	Sept. 6	14
6.....	...do....	Sept. 7	15
7.....	Aug. 25	Sept. 13	19
8.....	Aug. 30	...do....	14

OVIPOSITION IN TIDEWATER VIRGINIA.

All the pupal cells obtained in 1916 were placed in a large cage, and adults began to issue in July. Table II shows the date of copulation, the number of masses of eggs deposited by each female thus separated, and the total number of eggs deposited. A pair in copulation was isolated and a record made of egg laying. Flowerpots containing an equal mixture of sand and soil, having an abundance of organic matter, and about 9 inches in depth, were used for study, and were examined frequently, the examination being greatly facilitated by the ease with which the soil was removed entire from the

pots. This simulated natural conditions as nearly as possible. Glass jars containing 6 inches of soil were also used.

When the pots were examined the female was very often surprised during oviposition. On one occasion the burrow leading from the surface to the bottom of the pot was excavated along one side of the pot, so that the actual manner in which the nest was prepared before the eggs were deposited was observed. In this instance the beetle had widened the burrow considerably, forming an egg-shaped cavity with the larger end towards the bottom of the pot. Its head was turned upward, and was evidently used in the formation of the cavity. The pot was replaced in its normal position and several days later, when again examined, revealed the following conditions: When the pot and about half an inch of the soil were removed, several eggs, each separated from the others, were found, as shown in Plate I. These were removed, with a layer of soil, when other eggs were found, the process being continued until the entire mass of 27 eggs was removed.

TABLE II.—*Number of eggs laid by bred adults of Cotinis nitida, Norfolk, Va., 1916.*

Cage No.	Copulation date.	First mass.		Second mass.		Third mass.		Fourth mass.		Total number of eggs deposited.
		Date.	Number.	Date.	Number.	Date.	Number.	Date.	Number.	
a ¹	July 25	July 27	56	.....	.....	.....	.....	.....	.....	56
b.....	July 31	Aug. 2	20	Aug. 4	16	Aug. 18	14	(2)	33	83
c.....	do.....	Aug. 4	23	Aug. 14	14	do.....	9	Aug. 28	8	54
d.....	July 28	do.....	13	do.....	8	do.....	9	Aug. 20	8	38
e ²	July 31	Aug. 2	12	Aug. 4	38	Aug. 16	27	Aug. 28	16	93
f.....	July 29	do.....	14	Aug. 14	14	Aug. 18	8	.....	.....	36
g.....	Aug. 1	Aug. 4	22	do.....	29	.....	.....	.....	.....	51
h.....	do.....	do.....	27	Aug. 18	20	Aug. 28	27	.....	.....	74
i.....	Aug. 8	Aug. 14	15	.....	.....	.....	.....	(2)	15	30
j.....	do.....	Aug. 18	19	Aug. 24	10	Aug. 28	7	.....	.....	36

¹ Female escaped, all eggs found deposited in one mass.

² Dissected.

³ Female taken from pupal cell, copulated soon afterward.

It is evident that the female after preparing the burrow or nest, as already described, deposits several eggs and packs soil around them, continuing the process, layer after layer, until the entire mass is deposited. Since the packing is very thorough the mass of eggs separates from the nest very readily if moist, creating the impression of being deposited in a ball of soil.

The number of eggs deposited at one time or in a mass varies from 12 to 27. In one case 56 eggs were found, but since two sizes were observed at one time it would seem that the female, if not disturbed while in the nest, returns and deposits other masses. When disturbed, as was necessary in cage experiments, four masses of eggs were the highest number deposited by a single beetle, as shown in Table II.

It is evident that a female after depositing a mass of eggs comes to the surface to feed or to rest, later returning to the burrow (in cages, only if the nest is not disturbed) to deposit other eggs, and continuing this until the quota of eggs is deposited. Such are evidently the natural field conditions. In confinement the females were disturbed and new nests had to be constructed each time they desired to oviposit. This probably accounts for the long period of egg laying (nearly a month) as shown in the tables.

LIFE HISTORY OF THE LARVA.

When the embryonic larva is ready to hatch it causes the egg to split transversely at a point where the head and anal end of the larva touch within the egg. Immediately on freeing itself from the eggshell it becomes quite active, crawling on its back as do the older grubs when placed on the surface of the soil. In two instances a recently hatched grub crawled at the rate of 15 inches a minute, and nearly mature individuals travel over 2 feet a minute.

The grubs grow very rapidly, feeding on animal manure and similar decomposing matter, and their presence becomes more conspicuous daily. They are most noticeable in the late fall, and it is at this time that complaints are most frequent.

The first grubs hatch the first of August, and often by the middle of that month they become noticeable in lawns and gardens. At this time numerous young grubs will be noticed in the same areas, as though they worked in colonies, which is to be expected, since a number of eggs are laid close together. Later the larvæ scatter, and infestation of the lawn or garden becomes more or less uniform.

The grubs have distinct open burrows which average 6 to 12 inches in depth, although late in the fall they may reach a depth of a foot and a half, and the surface hole is about the size of one's thumb. The burrows usually go almost straight down, although there may be lateral burrows, and during the day the grub is likely to be found at the bottom. At night dirt is thrown out at the exit of their burrows, the little mounds of earth thus appearing being from 2 to 3 inches in diameter and closely resembling ant hills, the particles of earth being somewhat coarser, but not as coarse or pasty as is earth excavated by angleworms or nematodes.

Toward winter the grub usually deepens its burrows, and during the colder months remains inactive at the bottom; but it is quickly revived even during short periods of warm weather, and not infrequently continues its work on warm days. In fact, even as far north as Louisville, Ky., the grubs are active during parts of the months of January and February.

As warmer weather returns in the spring the grubs likewise make their normal reappearance, and after a short period of feeding be-

come full grown, prepare their pupal cells a few inches to 8 inches below the surface, and pupate within these. Pupation takes place the latter part of May or first of June.¹⁰

During cold spells in late fall and during winter, the larvæ penetrate deeper into the soil. In tidewater Virginia certain crops are grown during winter under frames, and in such cases, when weather conditions are mild, the larvæ may continue active during the entire winter. In the field, the larvæ are active during warm spells in winter, otherwise they remain inactive in the ground at a depth of from 7 to 10 inches. Early in spring activity is much increased, and as the larvæ are approaching full growth at this time they often prove injurious to plants sown at this time, and to others that are set out. The larvæ continue active until the beginning of June, their activity ceasing gradually as the time for transforming to pupæ approaches. By the middle of June the majority have transformed.

The newly-hatched larvæ can live several days without feeding, as long as the soil is moist.¹¹

Observations on the feeding habits of the larva of the green June beetle in the field in tidewater Virginia were made frequently from the time the larvæ were first hatched until they were ready to pupate, and these, together with the experience of experts and farmers who have had practical experience with this white grub, will serve as a criterion in judging the injurious status of the larva to crops.

From the time the larvæ hatch until some time after the first molt, they invariably work in the vicinity of where the eggs were deposited. Later they come nearer the surface of the ground. In the trapping experiments conducted for control, only larvæ that had molted at least once were captured, indicating that before that stage is reached they do not usually come to the surface. After the first molt, the larvæ are about three-fourths of an inch in length when extended. They become exceedingly active and their abundant numbers in the soil are plainly visible by the numerous perforations and ridges produced around the plants.

Probably the most important factor in judging the injuriousness of the larvæ is their extreme activity in the soil. This activity is in large measure responsible for the damage they do to crops. Where larvæ are abundant seedling plants are thrown up from the soil or buried beneath. In several instances two to three replantings have been found necessary before a fair stand of plants could be obtained

¹⁰ The notes in some of the foregoing paragraphs are also recorded by Davis and Luginbill (45).

¹¹ In vials of moist sand containing no food whatever larvæ were kept alive for three or four days after hatching without any apparent effect on their health. The data in regard to the molts of the larva were determined by confining larvæ in vials and supplying them with fresh food daily by changing the soil. The soil was prepared by mixing sand and compost in equal proportions. Under these circumstances the larva was reared from the time it was hatched until it changed to pupa. The number of molts was thus determined.

(see Pls. V and VI). Many fibrous roots are broken either by the movement of the larvæ traveling from one place to another below the surface or by their feeding when desirable food is near the roots. Certain methods of farming or trucking, particularly those deemed necessary in growing such crops as parsley, lettuce, celery, beets, and turnips, where the seed is sown in drills, afford ample opportunity for the young seedling plants to be injured as stated. Later, in such crops as parsley, for instance, where the plants are grown in close rows, the roots act as a barrier to the movement of the larvæ; hence they are much injured, and the outer leaves of the plants turn yellow, giving additional indication that root injury has taken place. Furthermore, the habit of the larvæ of coming to the surface at night, or of working close to the surface of the soil during cloudy days, is responsible for the undermining and uprooting of many larger plants. The carriage of soil into the heart of the susceptible crops mentioned also causes the plants to become choked, and is likely to produce rot. In many instances rows of plants have been found thus injured, lettuce being the greatest sufferer in this respect.

The object of the larvæ in coming to the surface at night probably is to change their feeding areas. Hundreds of larvæ may be observed traveling promiscuously, and the fact that the light of a lantern causes them to become stationary, or immediately to bury themselves beneath the surface, has prevented the determination as to whether or not they feed on the surface.

Where the larvæ occur abundantly the continual stirring up of the soil renders it unfit for the growth of crops of any kind. Innumerable tracks are made by the larvæ while crawling on their backs, and as they crawl over plants leaves are buried, or soil carried into the hearts of growing plants.

NUMBER OF MOLTS.

During the growing period the larva molts twice, a third molt occurring when the larva transforms to pupa.

A large series of larvæ were successfully carried through the molting stages in tidewater Virginia, and it was determined that the vigor of the larva when hatched, the richness of the food during its active existence, and the frequent changing of the soil all played an important rôle in determining the period before the larva molts. In other words, when all conditions are favorable for rapid growth, including warmth and the necessary moisture, the time between molts is comparatively short. From the time the larva is hatched until the first molt the minimum period observed was 13 days and the maximum was 27. From 38 larvæ carried through the molting stages the average number of days before the first molt occurs was determined to be 18. The minimum and maximum number of days

before the second molt occurred were 15 and 32, respectively, while the average number of days between the first and second molts was 26.

Thus a larva hatched July 27 will molt the first time in 13 to 15 days, or about August 11. The second molt will take place in about 20 to 25 days, or approximately the first week in September; from the latter date until late in the following spring, a period of nearly 9 months, the larva grows, hibernates, and matures before it finally transforms to pupa.

PUPATION.

When about to transform to pupa the larva constructs a cell by cementing particles of soil together. Several days after the cell is constructed the last larval skin is cast, disclosing the pupa. On opening the pupal cell the third or last molt of the larva may be

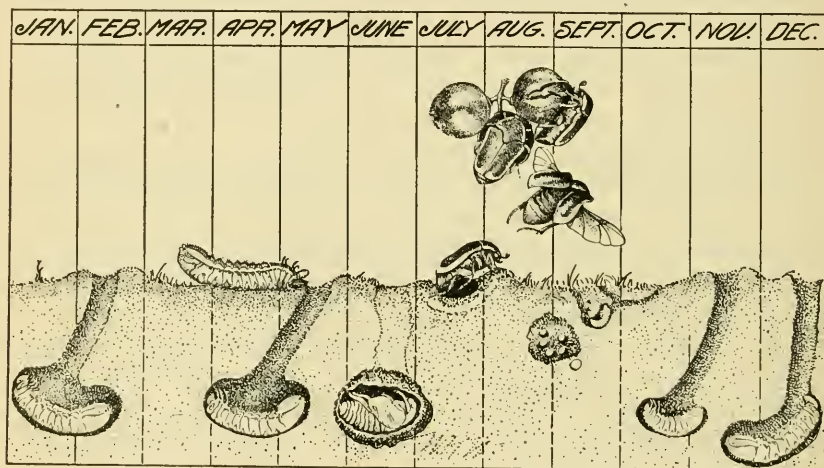


FIG. 5.—Diagrammatic picture showing life history of green June beetle. (Walton del.)

seen. The time required to change from larva to pupa in the cell varies from 3 to 8 days, according to temperature. The pupal period consumes three weeks or more, also depending on temperature.

Cocoons from which the adults have escaped are shown in Plate IV, B.

SUMMARY OF THE LIFE CYCLE.

The life history (fig. 5) of the green June beetle occupies only one year. Approximately four-fifths of this time is spent in the larval form. The most active growing larval period occurs in the first 2 months of its life, although 7 additional months are required in completing full growth.

In tidewater Virginia the beetles appear about the middle of June, continue through the months of July and August, and disappear by the first week of September. Eggs are deposited from the middle

of July and through the month of August in the soil at a depth of 6 to 8 inches. The eggs hatch in from 10 to 15 days, and the larvæ pass their lives in the soil, feeding and molting twice by autumn. By late fall the larvæ have become three-fourths grown—in some instances nearly full grown—and pass the winter in the larval form, either inactive or active, depending on temperature conditions. Early in the spring the larvæ resume feeding until the latter part of May and the first week in June, when they finally form cells in which they transform to pupæ. The pupal or dormant stage lasts about three weeks, and the adults begin issuing from about the middle of June onward.

LARVAL FOOD HABITS.

Experiments to determine if larvæ feed on the roots of plants must necessarily be taken for what they are worth, for the reason that confining the larvæ in a given area, as in flowerpots or boxes, places them under conditions subject to the will of the experimenter, and the larvæ invariably will net results subject to the conditions imposed on them. These results, therefore, may be misleading.

In confinement wheat plants were grown to provide food for the larvæ, and Riley (20) states that the larvæ feed on the roots of the plants. The following experiments for the purpose of determining this factor were conducted by the authors. An equal number of larvæ were confined in 8-inch flowerpots under the following conditions:

Experiment No. 1.—In a flowerpot containing pure sand the larvæ were very restless and worked the sand over thoroughly, evidently looking for food, or a means of escape. Some of the larvæ succeeded in moving the broken pieces of stone at the bottom of the pot and escaped in that way.

Experiment No. 2.—In a flowerpot containing pure sand, with a growing cucumber plant, the larvæ fed on the soil surrounding the plant roots and on the roots of the plant, even gnawing the stem 1 or 2 inches above the ground.

Experiment No. 3.—In a pot containing garden soil they fed on the organic matter.

Experiment No. 4.—About 25 larvæ were placed in a large battery jar with moistened earth, October 12. On the 17th, believing that the larvæ might be more hungry than when received, some beet roots were placed in the jar with the leaves remaining. These leaves touched the surface of the earth, and when they were examined two days later it was found that the stems had been cut in most cases, and that the leaf and stem together had been drawn down into the cells of the larvæ 5 or 6 inches below the surface.

Experiment No. 5.—A small lot of larvæ was separated from the main lot and placed in another jar with a large tuft of grass, roots, and all the grass blades, and treated in the same manner, but the roots were not materially affected. This experiment suggests that there can be no doubt whatever that larvæ feed, to a certain extent at least, on vegetation, and that this is done when they come to the surface of the earth, which they so frequently do at night, particularly after rainy spells. It also suggests that ordinary poisoned baits of grass or other vegetation strewed about the lawns and golf links where these insects are so injurious would be a more or less effective remedy, as the insects feed enough so that if the vegetation were well poisoned and strewed in such manner that it would attract the larvæ for protection as well as food beneath, they would eat enough to be killed.

Experiment No. 6.—Still another experiment was made with about half as many larvæ, which had been kept without food for several days. A beet root and a small cabbage plant were placed in a jar so that the leaves all projected. The beet was not touched the first night, but five small cabbage leaves were dragged under the surface. In each case the leaves were left and the stems were attacked first. In the case of the fifth leaf the stem had been about half eaten and dragged under.

Experiment No. 7.—In a pot containing garden soil and a growing cucumber plant most of the larvæ were found feeding on the soil. One larva, however, was observed feeding amongst the roots of the plant, many fibrous roots were broken, and others had been injured by the larvæ feeding upon them.

HABITS OF THE ADULT.

The beetles make their first appearance above ground during June in the middle Atlantic region and not until July in the more northern range of the species, the exact time being dependent on atmospheric conditions, especially temperature. They gradually become more abundant until August, after which time their numbers usually diminish or at least become less noticeable.

During their periods of abundance the beetles, according to Davis and Luginbill (45),¹² appear about daybreak, the females appearing first, at least relatively more frequently than the males, from daybreak until after sunrise. Shortly thereafter the females begin to settle to the earth, often first searching for the exit of a burrow or starting a fresh hole and then resting in the grass preparatory to mating. By this time the males predominate, becoming relatively

¹² Observations were made at Louisville, Ky., except as noted and are substantially as already published.

more abundant as the morning advances, and the number of females gradually diminishes. By 7 a. m. (later on cloudy days) the males are exceedingly numerous, buzzing here and there in search of females. In heavily infested localities the air near the ground becomes "alive" with the beetles, which fly rapidly back and forth, buzzing incessantly, giving the impression of a clover field humming with bumblebees. They usually fly 6 to 12 or 18 inches above the ground, but often higher.

From observation it appears quite certain that the male is attracted to the female by the rather strong and sickening odor of a milky fluid secreted by the latter, for he usually drops to the ground within a few inches of a female and, searching through the grass, seems to have no difficulty in finding her within a minute or two. Male beetles will alight near a female even when the latter is completely hidden from view. In one case a male was seen attempting to mate with a dead female, and as she was lying on her back it is hardly probable that form or color was the attractive force. Often one finds a "nest" of beetles in the grass, there being a number of males and only one female, more often a male and female in copula and the other males vainly endeavoring to copulate with her. In such a "nest" as many as eight males have been observed attempting to mate with one female. From these facts, and since the female invariably secretes this odoriferous fluid, it is believed that the females are detected through the sense of smell.

Mating lasts only a few minutes, for, as a rule, after this space of time the female forcibly frees herself from the male by entering her burrow or crawling under matted grass. In one instance a pair was found in copula about 5 inches below the surface in the soil of a breeding cage, and even after their removal from the cage they did not separate for some time.

From 8.30 to 11 a. m. the number of beetles gradually diminishes and after that comparatively few are seen in flight. By 1 p. m. and throughout the afternoon only an occasional beetle is observed flying about. On one of the days when observations were made it rained most of the morning until 10.45, after which the sun came out and the beetles appeared in numbers. At Columbia, S. C., the beetles were most active between 11 a. m. and 3 p. m., being quite difficult to capture at this time, since even when feeding they took flight at the least disturbance. Evidently most of the beetles spend the night in the soil or under débris of one kind or another, but males were occasionally found at night resting in shrubbery, quite inactive and not feeding, nor were they attracted to the electric light carried by the observer.

On entering the ground the beetle throws up a little mound of earth not unlike that made by the grub (see p. 21). The mound resembles

a small ant hill, but differs in that the particles of earth are coarser. (Pl. VII.) More often the males, after their daily flight or after mating, burrow just beneath grass or loose sod, and in the case of the putting greens of a golf course which are kept perfectly level and the grass closely clipped, small mounds, resembling miniature mole burrows, indicate the presence of a resting beetle beneath. The females after mating go deeper into the soil, that is, from 2 to 4 or 5 inches, where they lay the eggs for the next generation.

The beetles evidently detect their food by the sense of smell. An overripe fig was placed in a rearing cage with a number of beetles which had not fed for several days. Immediately one about 6 inches distant moved its head as though scenting the odor, circled the fruit, and soon thereafter moved directly toward it and began feeding on it. In another cage beetles refused ripe figs which were not bruised, but when the skin was removed immediately attacked them. While this does not definitely prove that the beetles will not attack perfectly ripe fruit it tends to show that they are not attracted to fig trees except by the odor of bruised fruits and it is of course possible that they may when abundant attack fruits both perfect and injured.

HISTORY AND LITERATURE.

While the literature of the green June beetle is large and there are many unpublished notes in the Bureau of Entomology, it will not be necessary in this article to mention any but the more interesting facts, which have a bearing upon the destructiveness and the plant-feeding habits of the species.

In the original description of the species, published in 1758 by Linnaeus (1, p. 350), the name *Scarabaeus nitidus* was used. "*Habitat in India*" was obviously erroneous. The genus *Allorhina* or *Cotinis* is neither European nor Asiatic, and there is no doubt that *C. nitida* is a native American species. The second habitat, "Carolina," mentioned by Linnaeus (2, p. 26), refers to either North or South Carolina.

The first account of the habits of this species was published in 1865 by Dr. B. D. Walsh (3). Early records of the Bureau of Entomology show that the larva was probably first reported to attack useful plants in 1868, by G. G. Baker, who observed it in strawberry beds at South Pass, Ill. The larvæ were confined with wheat roots, of which they devoured great quantities. April 15, 1868, they were found in cocoons; by May 14 the change to pupa had taken place; and by June 2 the adults had issued.

Mention of the green June beetle was made by M. D. Thompson (4) of Illinois in 1869. He stated briefly that the grubs feed on the

roots of plants and sometimes become quite injurious to the strawberry. It is rather strange that this species should have first attracted attention in Illinois in the most northern boundary of its present habitat; when we take into account that it is normally a habitant of the South. It was reported again from Illinois in 1874 by William LeBaron (5, p. 89-90).

In 1879 Dr. L. O. Howard (6, 7) noted September 15 that the larvæ were found crawling on their backs in immense numbers on the grounds around the Capitol at Washington, D. C., and that after heavy rains at that season they were sometimes so numerous that bushels had been swept away together. They were also found crawling about the pavements of the Department of Agriculture. September 5, 1881, Mr. B. P. Mann brought in grown larvæ which had been found around the roots of a pear tree.

In 1883 William Saunders (8) gave a brief account of this species with an original figure.

The first general account of this insect was given by Forbes in 1884 (9, p. 149-150). In this article Howard's previous paper is quoted and characters are given for the separation of the beetle and its larva from those of *Lachnosterna* (*Phyllophaga*). A similar article was published by the same author in 1884 (10, p. 245). In 1884 also C. W. Leng (11) recorded an abundance of this species in the Carolinas and Georgia, including notice of injury by the beetle to walnut trees.

In 1885 Dr. J. A. Lintner gave a general account (12) of the feeding habits of both larval and adult stages.

In 1887 Dr. W. H. Ashmead (13, p. 16) mentioned the feeding of the adult on corn in the ear.

In 1888 W. B. Alwood (14) reported the successful use of kerosene emulsion against the grubs on the Capitol grounds at Washington, D. C. The same year Messrs. Riley and Howard (15) mentioned the feeding of the adult on the fungus *Roestilia aurantiaca*, and the following year (17) reported an abundance of beetles and their injury to peaches in the District of Columbia.

Reports from Kentucky in 1890 (18) by Prof. H. Garman and C. W. Mathews indicate that the grubs were injurious to strawberry and the beetles to fruits, particularly grapes. In 1891 W. B. Alwood (19, p. 26) stated that he had bred a dipterous parasite from the adult. In 1895 Garman (23) further reported that the grub "feeds on living roots of grasses, strawberries, and other plants, and never, as far as I can learn, eats dead vegetable matter." The beetles were also observed feeding in the husks of corn when the grain is in the dough stage, boring in the latter often well down to the base of the ears, and they sometimes proved annoying to the honeybee by persistently trying to enter beehives.

The importance of the species as a truck-crop pest was further noted by Riley in 1893 (20), when he stated that an acre of celery at Rives, Md., was found fairly teeming with the grubs. No direct injury was noted to the roots, but the heart of the celery became choked with soil, and rot was induced by the acid excrement of the larvæ. The great abundance of the larvæ on this area was attributed to heavy mulching with rotten straw, the odor of which obviously had attracted the parent beetle to deposit her eggs. The same year Dr. J. B. Smith (25, p. 510-511; 26) stated that the larvæ in 1896 were more abundant than those of May beetles, and that their work beneath the sod is sometimes so rapid and complete that the whole can be rolled up like a rug, every fiber of the roots having been destroyed. Forbes (22, p. 280-281) stated that this grub is normally a grass insect, but also infests strawberry fields.

From Ruxton, Md., it was reported that in 1897 hundreds of California privet plants were destroyed by the grubs.

The conviction of the authors engaged in truck-crop insect investigations, that the larva is more injurious than the beetle, is not shared by all entomologists. M. V. Slingerland (24) wrote that the grubs during growth are harmless, feeding largely on vegetable humus, but when they attain growth, they often injure roots of strawberry plants and grasses.

In 1898 Dr. Howard (28) wrote a somewhat extensive article on the green June beetle in which the statement was made that the actual amount of damage done by the larva was problematical, and in fact that it was doubtful whether the larvæ normally do damage at all. In spite of this, numerous records of injury had been made long before this date, some of which Dr. Howard noted, and a considerable number of reports have been received since, particularly during recent years, when many complaints have been made of injury by white grubs, which proved on receipt of specimens to be *Cotinis nitida*.

In 1900 the senior author (29, p. 55), in an account of insects and the weather, stated that this species was less abundant in the District of Columbia than usual. The same year J. B. Smith (30, p. 282) gave notes on the habits and occurrences of the species in New Jersey. The following year the senior author (31, p. 76-77) reported injury by the grubs to greenhouse plants, but the injury might have been partly due to cutworms.

In 1905 Dr. Forbes (35, p. 101-103) published a general account which included notes on the characters of this and other so-called species of "June beetles."

In 1909 Prof. H. Garman (35), in writing of this species, stated that it was destructive to corn planted near manure heaps and mentioned injury by the beetles gnawing the tips of ears of corn.

In 1910 Prof. W. S. Blatchley (37, p. 995-996), after furnishing a technical description of the species, gave some brief notes on its habits, including some references. The same year J. B. Smith (38, p. 321, fig. 129) published notes on the occurrence of this species in New Jersey, and in 1910 (39, p. 444) reported injury to lawns by the larvæ in southern New Jersey, recommending kerosene emulsion.

In 1914 Prof. E. N. Cory (40, p. 13-15) stated that the adult did serious damage to corn by cutting holes in the leaves. He recommended a rigid cleaning up in the fall and fall plowing. The same year Prof. Franklin Sherman, jr. (41) published a summarized account of this and other species of grubs. The same year also Slingerland and Crosby (42, p. 296-298) gave a concise account of this insect as a pest on peach and other fruits.

In 1921 Mr. J. J. Davis and Mr. Philip Luginbill, Bureau of Entomology (45), furnished the most complete account of this species that has heretofore been published. It includes many instances of injury, especially to lawns and golf greens, and a most excellent account of the life history and habits, together with technical descriptions of the different stages. It also contains a consideration of natural enemies and methods of control, especially with regard to the occurrence of the insect in lawns and golf greens, and a bibliography of economic literature.

CONTROL BY NATURAL AGENCIES.

White grubs in general have many natural enemies without which there is no doubt that injuries from this source would be much greater. The grub of the green June beetle is without doubt largely held in control by natural enemies.

INSECT ENEMIES.

BLOW-FLY PARASITES.

In the vicinity of Norfolk, Va., two species of parasites were reared from the pupa and adult of *Cotinis nitida*, one of which proved to be new.

Sarcophaga utilis Ald. was reared from the adult, and as many as two and three parasites were obtained from a single parasitized individual. This parasite is a comparatively large-sized species and sometimes occurs quite abundantly along the seashore. Hundreds of these flies were observed frequently on seaweeds along the coast, sometimes alighting on any marine animal matter cast up by the sea. From the number of the parasites observed it would appear that this species is a natural inhabitant of this locality, and might prove parasitic on other insects besides *Cotinis nitida*. The habits of this fly are not definitely known in regard to its method of ovipo-

sition on the host. Several beetles were observed with larvæ attached to their bodies near the base of the head and thorax, and it may be that the parasite normally deposits its larvæ on that part of the host. The reason for this belief is that parasitized beetles which have been examined usually have their heads severed at the junction of the thorax. A large number of beetles thus examined also have the contents of the thorax and abdomen devoured by the parasitic larvæ. When the parasitic larvæ become mature they leave the body of the host and transform to pupæ either at or a little below the surface of the soil.

Sarcophaga (Helicobia) heliciis Towns. was reared both from the pupa and adult. It is only about half the size of the former, but is more commonly parasitic on *Cotinis nitida*, and is known as a parasite on a number of other insects. It is quite common in many localities and is widely distributed. The rearing of this species from the pupa of *Cotinis* leads to the question as to how the adult parasite oviposits (33, p. 25). Evidently the larvæ must be parasitized, and in order to reach the host the only plausible method is for the parasite to enter the ground and deposit the larvæ on the host larvæ. Considering the habit of this white grub in making perforations to the surface of the ground, it would be an easy matter for the fly to enter a burrow leading to the abode of the host and parasitize it.

The ability of the host larva to live for a considerable period after being parasitized, and even to pupate in many instances when pupal cells were found with the parasitic larva, is somewhat remarkable.

An instance of this is recorded by Mr. H. A. Morgan, Bureau of Entomology, when *Sarcophaga (Helicobia) heliciis* Towns. was reared from grasshoppers, and it was found that the functions of the grasshopper, including mating and ovipositing, continued normally for a period of 95 days, notwithstanding the fact that it harbored the parasite for that length of time.

Pupal cells contained as many as six or more parasitic larvæ of *Sarcophaga heliciis*, and the contents of the cell were completely devoured. In some instances the last larval skin of the host larva was found in the cell, indicating that the larva was able to transform into pupa before succumbing to the attacks of the parasitic larvæ.

In laboratory observations the parasitic larvæ after becoming full-grown transform to pupæ on the surface of the ground or become attached to the body of the beetles when they emerge from that source, or may even enter below the surface of the ground for some distance.

The good service which this latter parasite may render is, however, problematical. Reasoning from Morgan's observations on grass-

hoppers, the function of mating and egg laying by the beetles might continue normally in spite of their being parasitized.

A DIGGER-WASP ENEMY.

Among the known natural enemies of the green June beetle, if we except such birds as robins and blackbirds, is one that is more than probably responsible for the extreme fluctuations in the numbers of this species observed in some years and in certain localities.

During the months of August and September of the last decade of the nineteenth century, on numerous occasions the flight of a digger wasp, *Discolia dubia* Say (fig. 6), was observed by the senior author. The wasps gradually increased in numbers until they became sufficiently abundant to attract general attention. The same abundance



FIG. 6.—The digger wasp (*Discolia dubia*): a, Female wasp; b, antenna of male; c, cocoon showing opening above. Twice natural size.

was reported in other quarters in the city of Washington, and it was presumed that white grubs of some sort were the attraction. Finally it was learned that the insect seemed to be present only in the male sex. Later the species was reared from *Cotinis nitida* in different localities and reported to the Bureau of Entomology.

In Maryland, near Washington, the same phenomenon was witnessed, and it was also noted that the wasps congregated in great numbers on convenient shrubbery. It may be said in general that the wasp is most conspicuous on lawns and near shrubbery in just such localities as are frequented by its host. One year this species was so abundant in some of the smaller parks of Washington and so disturbed the children who used the parks for playgrounds that the wasp became the subject of newspaper notice.

A few words in regard to the digger wasp above mentioned may be interesting. It is one of our medium-sized species, measuring

about three-fourths of an inch from head to tip and with a wing expanse of about an inch and a fourth. It is subject to considerable variation, however, in size. The main color is black; the wings are dusky with a purplish luster; the first two segments of the abdomen are similar, but the remaining abdominal segments are reddish brown, the third segment being marked above with two conspicuous transverse yellow spots. The female has comparatively short antennæ, and those of the male are nearly twice as long.

In large collections which have been made and in observations the male greatly predominates, females being decidedly rare. The males are also more slender and smaller than the other sex and are provided with strong clasping organs, which perhaps have the power of puncturing the skin. The female is undoubtedly a poisonous stinging form. The cocoon of this species is shown in figure 6, C.

Our first report of this natural enemy of *Cotinis nitida* was received from Mr. F. W. Barclay, Haverford, Pa., who wrote October 12, 1903, and sent numerous specimens of nearly grown larvæ as well as cocoons, showing dead beetles, and cocoons of this digger wasp. He stated that the grubs at that time were becoming scarce. He had observed two of these wasps enter holes made by the grubs and remain there for a few minutes. It was the general opinion of the men working on the grounds of the golf links at Haverford, where the grubs were most injurious, that the wasps sting and kill the grubs. If the grubs were dug up after the wasp had entered the holes, the wasp would be found attached to them. He also stated that the wasp killed the grubs, attacking them on the golf greens in the morning.

We also have record of this species occurring as a parasite of the green June beetle at Harrisburg, Pa., made by the late H. O. Marsh, Bureau of Entomology, about the middle of August, 1906. Numerous individuals were observed flying over soil known to be infested by the host larva and the wasps were observed to crawl into the burrows made by the host.

June 6, 1908, Mr. W. A. Kapner, Charlottesville, Va., wrote that he had seen a wasp of this species collected September 21, 1907, carrying a larva of the beetle when taken. Swarms of the wasps were flying in the autumn of 1907. In a later letter, June 12, our correspondent stated that the wasp was seen dragging the host larva. No doubt the females of this species are quite capable of doing this work, although it would seem to be unusual for the group to have this habit. It is remarkable in any case, since the wasp is so light as to be seemingly incapable of flying with so large an object as this grub, unless the latter is of small growth, more particularly because the grub is usually full of humus and moisture, making it quite heavy for its bulk.

There is no doubt that the female wasp often crawls into the burrows and deposits her eggs on the larvæ, while on other occasions she may drag and fly about with small larvæ until she finds a hole or makes one herself. It has been stated by certain entomologists that wasps of the family Scoliidae are not known to have the power of building nests or of transporting their prey to them for their carnivorous larvæ, in this respect differing from many other solitary wasps such as the cicada killer (*Megastizus* [*Sphecius*] *speciosus* Dru.), whose habits are well known. On the other hand, J. B. Smith has written that they burrow into the ground in search of white grubs, in which they lay their eggs and on which their larvæ develop. That this habit is true of *D. dubia* was proved by additional observations conducted in 1916 at Hampton and Diamond Springs, Va., where the wasp was observed entering openings of the burrows. Many dead larvæ were in evidence at the openings, indicating that the wasp larvæ had fed on them.

It is worthy of note that the presence of the grubs of this species might have escaped notice on the grounds of the Department of Agriculture were it not for the unusual appearance of the wasp parasites *Discolia dubia*, which were noticed first in 1897 and for many years thereafter. During a period of 15 years there was no evidence of attack by the larvæ of the June beetle in Iowa Circle, a little more than a mile north of the affected patch in the department grounds.¹³ Both are heavily manured each spring and the Iowa Circle grass is kept moist by constant use of a hose during the warm season. This may account for the discovery made September 10, 1916, that the ground was almost honeycombed with the holes made by the grubs on the latter grounds, a fact which would have entirely escaped notice had not the wasp *Discolia dubia* drawn attention by disappearing entirely in the earth. Upon examination numerous holes were found wherever there were heaps of earth, and these were at intervals of no more than an inch.

MISCELLANEOUS.

There are no doubt many other predacious insect enemies of the white grub under consideration but they have not been reported.

Two individuals of *Scarites subterraneus* Fab. were observed in the District of Columbia, May 17, 1914, associated with larvæ of *Cotinis nitida*, which was said to be injurious to iris.

In the control experiments at Norfolk, Va., where flowerpots and troughs were used, a carabid or ground-beetle, *Cychrus elevatus* Fab., a nocturnal sandy-looking spider, and the northern mole-cricket

¹³ A parallel case may be cited for the yellow-necked flea-beetle (*Disonychia mellicollis* Say), which was found one year in great abundance at Iowa Circle, in Washington, D. C., and very rarely in the department grounds on the same food plant.

(*Gryllotalpa borealis* Burm.) were observed, but it is questionable if any of these actually feed on the larvæ.

Macrocheles marginatus Herm., a mite, according to Harry B. Weiss, has been found attached to the adults of this species.

A FUNGUS PARASITE.

Adults of this grub are often found dead and their bodies covered with a fungous growth. In some instances, when a pupal cell was opened, the pupa would be found dead, apparently from the effect of some fungous disease.

In rearing cages maintained by the cereal and forage crop insect investigations the grubs were noted to be attacked by the green muscardine fungus (*Metarrhizium anisopliae*).

The same fungous disease was observed attacking the larvæ at Norfolk, Va., during July, 1916.¹⁴

From what has been stated in regard to the control of this species by natural enemies, the evidence is that this manner of reducing the numbers of both beetles and grubs, especially the latter, is of the highest importance. In the District of Columbia, and probably in many other localities in similar latitudes, including portions of eastern Pennsylvania, the digger-wasp, *Discolia dubia*, has controlled this species for several years. In other localities perhaps other predators are largely instrumental in holding the pest to normal numbers; and the numerous bird enemies, especially the crow blackbird, are also very efficient destroyers. It has already been stated that the habit of the larva of coming to the surface of the ground after storms also serves as a means of repression, in that it exposes them to the attacks of agencies of various sorts, including man. Other atmospheric conditions are apparently inactive.

A BACTERIAL DISEASE.

A bacterial disease known as *Micrococcus nigrofaciens* has been recorded from the larva of this species, 96 per cent of the larvæ obtained from North Carolina in 1913 showing slight infection. So far as known, however, this disease exercises no appreciable effect on the numbers of the host.

MAMMAL ENEMIES.

Many instances have been recorded of the destruction of white grubs by wild mammals, such as foxes, raccoons, gophers, skunks, and chipmunks. The last two mammals mentioned and the opossum have been recorded as eating the grubs of this species. The much-abused mole destroys large numbers of the grubs on lawns and sometimes in gardens, but unfortunately it is difficult to determine which does the more damage to the lawns or gardens, the grubs or the moles.

¹⁴ Specific identification by Dr. A. T. Speare, Bureau of Entomology.

BIRD ENEMIES.

Of bird enemies one of the most important is the common crow blackbird or purple grackle (*Quiscalus quiscula*). In the case of this bird 75 stomachs were examined and found to contain the green June beetle, and in several instances 7 or 8 were found in a single stomach. The constantly increasing numbers of this bird on the grounds of the Department of Agriculture where the grubs of this species were formerly very abundant has undoubtedly been one of the causes of the insects' decrease. Robins and crows frequent the same locality and have undoubtedly helped toward the same end.

Domestic ducks, according to Davis and Luginbill (45, p. 22), have been observed to seek the grubs eagerly, but, as a rule, gather only those which are on or near the surface of the ground. Chickens occasionally follow the plow and destroy these insects; but, so far as we know, domestic fowls are of very little value in the control of this pest.

During July, 1882, Mr. John D. Wilkins, Selma, Ala., observed that the mocking bird (*Mimus polyglottos*), the blue jay (*Cyanocitta cristata*), and cardinal grosbeak (*Cardinalis cardinalis*) were feeding on the beetle of this species. The kingbird (*Tyrannus tyrannus*) and cardinal grosbeak have been recorded by the Biological Survey as enemies of this species. The robin (*Planesticus migratorius*) and the yellow hammer or flicker (*Colaptes auratus*) have been observed attacking the grubs. Other species of birds which have been found by the Biological Survey to feed on either larvæ or adults include the woodcock (*Philohela minor*), broad-winged hawk (*Buteo platypterus*), screech owl (*Otus asio*), pileated woodpecker (*Phloeotomus pileatus*), red-headed woodpecker (*Melanerpes erythrocephalus*), chuck-will's-widow (*Antrostomus carolinensis*), nighthawk (*Chordeiles virginianus*), crow (*Corvus brachyrhynchos*), red-winged blackbird (*Agelaius phoeniceus*), crow blackbird (*Quiscalus quiscula*), loggerhead shrike (*Lanius ludovicianus*), catbird (*Dumetella carolinensis*), brown thrasher (*Toxostoma rufum*), and wood thrush (*Hylocichla mustelina*).

METHODS OF CONTROL.

FOR THE BEETLES.

Remedial measures against the adults of the green June beetle have been tried, usually without success, by entomologists and other practical workers. In 1899 Dr. A. L. Quaintance, of the Bureau of Entomology, when working in the South, used poisoned

bait sweetened with sugar, but the beetles did not relish it. Others sprinkled poison on ripe fruit as a means of attracting the beetles, also without success. Prof. Henry Garman (36), Kentucky State zoologist, stated that hand picking for the adults seemed to be the only safe remedy.

If it were possible to destroy the beetles in larger numbers than has been done heretofore this would mean a great lessening in the abundance of the grubs, which, as we have plainly shown, are even more injurious than the beetles.

FOR THE GRUBS.

Numerous remedies which have been practiced successfully against the common white grubs (*Phyllophaga*) have been reported effective against the *Cotinis* grub, and again as useless. Years ago, according to Dr. L. O. Howard, an experiment was made which consisted of a modification of the bran-arsenic mash and met with success against this grub in a celery field.

POISONED BAITS.

There is little doubt that still better results might be obtained by using a grasshopper remedy, called the Criddle mixture, which may be modified to suit the grub under consideration. It has been used with great success in Manitoba. As originally used it consisted of 1 part of Paris green mixed thoroughly in 60 parts of fresh horse droppings, 2 pounds of salt to half a barrel of mixture being added after being dissolved in water. This is placed in a half barrel and drawn on a cart to the edge of the infested field, or one likely to be infested. The mixture is then scattered broadcast along the edge of the crop, or wherever needed, by means of a trowel or wooden paddle. The grasshoppers are attracted to it and are killed in large numbers by eating the poison.

A cheaper arsenical is white arsenic (arsenious oxid), used in the same proportion.

An application of poisoned bran mash was made at Norfolk, Va., November 18, 1914, in the field and under glass, but examination two days later failed to indicate results. It is believed, however, that if this remedy had been applied in September or October the grubs might have been killed.

COLLECTING AND HAND PICKING.

It has been shown repeatedly in different localities that after heavy rainfall these grubs are brought to the surface in large numbers, and it is not difficult to collect them early in the morning when

they are crawling over sidewalks and on unused ground. At such times they should be picked up and thrown into bags, barrels, or large baskets and promptly burned. Not infrequently they have been swept up from pavements and have received similar treatment. The same result may be obtained by flooding, which causes the grubs to appear at their exit holes in a few minutes.

Wherever it is possible to flood fields, such as lawns, celery beds, and similar areas, most affected by the grubs of this species, it should prove effective; in fact, one of our correspondents has reported that it is the only successful remedy that he has found on golf greens, and it should answer equally well for lawns.

Mr. Theodore Strohhaecher, of the Louisville Country Club grounds, stated to Mr. Davis that he had picked up as many as 3 quarts of grubs from a single putting green after flooding with water.

Collecting the beetles has been practiced to a considerable extent, and while this method may not be entirely effective, it is a means which should be adopted wherever practicable. Various methods have been adopted in different places. The Louisville Country Club pays the caddies for collecting the beetles, the work being done in the morning. At Hot Springs, Va., the golf club pays the boys so much a quart. Here they also used a trap which Mr. W. T. Bingham described April 30, 1914, as follows: "Wire netting was stretched on a frame 10 feet long and width of the roll (about 3 feet). This frame was set in a trough partly filled with water with a little floating kerosene. The beetles strike the netting and fall into the trough and the kerosene finishes them."

The time of collecting is of the greatest importance because of the habits of the females. They appear at daybreak and settle in the grass shortly after sunrise; hence, in order to destroy them, collecting must begin early in the morning. Also, collecting should start as soon as the beetles make their appearance in July, before they lay eggs, and should be continued throughout the month.

On an area of about half an acre at Portsmouth, Va., large numbers of grubs were picked by hand by following the plow (Pl. VIII, A). Some time later an application of kainit was made at the rate of 1,000 pounds to the acre. Less injury by the grub on this particular area was noted by the farmer. Undoubtedly the hand-picking had much to do with this success, but benefit from the kainit, while possible later on, has no direct noticeable benefit in destroying the grubs.

CARBON DISULPHID.

Carbon disulphid has been used for many years with varying degrees of success for different forms of white grubs and other subterranean insects. Its cost, however, is somewhat prohibitive, and while it

may be effective on a small scale it is scarcely applicable for large areas. It has been pronounced the most direct remedy or insecticide employed experimentally by the cereal and forage crop insect specialists.

Since the burrows of this grub are open they are easily reached by the fumigant, the poisonous fumes of which are heavier than air. Carbon disulphid is injurious to grass and to plant life generally when applied direct and it is therefore recommended that a funnel be inserted into the holes made by the larvæ and beetles before pouring in the required amount of liquid disulphid, in this case about a teaspoonful to each opening. A large copper engine oiler forms an efficient injector for this purpose.

Caution.—Care should be exercised in the handling and use of carbon disulphid, since it is highly inflammable and the fumes, when mixed with a certain proportion of air, are explosive. There should be no fire of any kind, such as a cigar, near by when handling the liquid.

KEROSENE EMULSION.

Kerosene emulsion was tested in 1888 by Mr. W. B. Alwood (14), when engaged in the Bureau of Entomology, on the Capitol grounds at Washington, D. C., where the grubs occurred abundantly on lawns. Application at the rate of 1 part of the standard mixture to 15 parts of water was made, and for several days afterwards the ground was kept freely soaked with water, with the result that not a single larva was found while the check plat adjoining contained numerous larvæ, only a few of which were dead.

Writing in 1901, Dr. L. O. Howard (32) stated that in experiments by Mr. Lull, formerly of the Bureau of Entomology, kerosene emulsion proved effective against such grubs as happened to be near the surface, but failed to reach those which were lower. Experiments with kerosene emulsion against the grubs of *C. nitida* conducted by others tally with the above observation.

TESTS WITH KEROSENE EMULSION.

Several experiments were conducted in the vicinity of Portsmouth, Va., with kerosene emulsion applied at the rate of 1 to 5 and 1 to 10 to cold-frame sash-growing parsley, using from 1 to 4 gallons of the liquid per sash. Tests were also conducted in the field, and in both instances the liquid was poured into the perforations made by the grubs, which extended from the surface of the soil to 6 to 10 inches below. At the time these tests were made the grubs were from one-half to three-fourths grown, and weather conditions were such that they worked at the depth mentioned above. It was not surprising,

therefore, that the results obtained did not fully substantiate expectations. Even at that stage of growth and at the depth mentioned, however, the liquid penetrated to the larvæ, and several grubs were found to have come to the surface, turned yellow, and perished. It is evident, as a result of these tests, that the success of kerosene emulsion as an insecticide where growing crops are concerned is dependent upon the stage of growth of the larvæ and the depth at which the grubs happen to be at the time of application. When they are young and work relatively near to the surface kerosene emulsion will prove more efficacious than when they are older and farther below the surface. In cold frames particularly, and in other instances where the grubs are known to be present and other methods of control suggested do not seem feasible, kerosene emulsion should be applied at the rate mentioned and be followed by a copious watering from a garden hose or sprinkler unless there are heavy rains.

EXPERIMENTS CONDUCTED ELSEWHERE WITH KEROSENE EMULSION.

Five additional experiments were conducted with kerosene emulsion with variable results. At Rosslyn, Va., an imperfect emulsion was made on golf links by using a barrel and a half of kerosene mixed with water and passing the oil and soap from one tub to another until an emulsion was supposed to be produced. This killed all the white grubs, but it also destroyed the grass. Still the experimenter was perfectly satisfied with the result. Other correspondents had the same experience, as usual not making a perfect emulsion. A correspondent at Saltville, Va., experimented with a combination of kerosene oil and castile soap, according to directions, but since an egg-beater was used in agitating the mixture, it was not properly mixed. It was applied *on the plants* with an ordinary water sprinkler, the grubs were killed, but about 75 per cent of the strawberry plants were injured.

Another experiment was made with the same imperfect emulsion which was poured *about the plants*. It killed the grubs *without* injuring the plants, as the leaves did not come in contact with it.

In experiments performed by Mr. Davis at Louisville, Ky., on golf links 80 per cent of the grubs in the treated area were killed by a single application of kerosene emulsion made at the rate of about 1 gallon to 6 or 8 square feet and afterwards thoroughly washed into the soil by copious sprinkling with water, a remedy which the Bureau of Entomology has recommended for many years for white grubs and similar forms of insects. An important point in the application of this insecticide is that it should be made as soon as the grubs become conspicuous, usually about the middle of September, or at about the time when they begin to crawl about on the surface of the ground.

PREPARATION OF KEROSENE EMULSION.

There are several forms of kerosene emulsion, but that used with fish-oil or soft soap has been found by years of experience to be the best.

Kerosene-soap emulsion is prepared by combining 2 gallons of kerosene, 2 pounds of fish-oil or other soap, or 1 quart of soft soap, with 1 gallon of water. Laundry soap, if dry, is shaved and dissolved in boiling water and then poured (away from the fire) while still boiling hot into the kerosene. The mixture is then churned rapidly for from 5 to 10 minutes, pumping the liquid back upon itself by means of a force pump and direct-discharge nozzle throwing a strong stream. At the end of this time the mixture will have become of the consistency of thick cream. Properly prepared, an emulsion will keep throughout a season and should be diluted only as needed for use. For most species of insects the staple emulsion should be diluted with from 10 to 20 parts of water. For this species a 10 per cent dilution has been found effective. In the preparation of kerosene emulsion a force pump is a necessity, since if not made according to directions a perfect emulsion is not formed. There is then danger of injury to the plants by the kerosene, as also useless waste of material.

After the emulsion has been applied it should be followed by a copious application of water from a hose in order that the insecticide may penetrate more deeply into the soil. In the preparation of kerosene emulsion other soaps than those mentioned may be used.

Where unskilled labor is employed, the operators should be carefully instructed as to the difficulties and intricacies involved in applying the emulsion that it may not be brought into direct contact with the plants, which might thus be seriously injured. Where laborers of the better class are not available, fish-oil soap and other soap solutions containing no kerosene are preferable.

TRAPPING METHODS FOR THE GRUBS.

Three methods for trapping the green June beetle larvæ were used experimentally during the fall of 1914 on the farms of Messrs. Fred and George Richardson, at Portsmouth, Va.:

(1) By placing boards on the surface of the ground; (2) by setting flowerpots in the ground; and (3) by constructing V-shaped troughs in infested fields.

THE BOARD METHOD.

Boards 12 feet long and 16 inches wide were placed closely together on the surface of the ground in a field infested with grubs

(Pl. VIII, B). Early every morning the boards were turned over, and the larvæ which had worked close to the surface during the night were collected in cans or pails. Several dozen larvæ were usually found under every board thus turned, and after several days the boards were shifted to new areas. Since this method necessitates a large amount of hand labor it is somewhat expensive.

THE FLOWERPOT METHOD.

A severely infested field was selected in which parsley was growing in beds 6 to 7 feet wide and 200 feet long, with the plants in rows 6 inches apart. Three-inch flowerpots with the bottoms stopped with corks were set between the rows of parsley 2 to 3 feet apart in the rows, with the top of the flowerpot about a half inch below the surface of the ground, the soil being packed around the pot in a sloping fashion (Pl. IX, B).

The habit of the grubs of coming to the surface at night and crawling on their backs proved to be their doom. In passing a flowerpot the larvæ invariably fall in, and owing to the smooth surface and steepness of the sides they are unable to crawl out. Two to three dozen larvæ were usually caught in one of these small pots. A bed containing approximately 150 pots would in the course of several days trap from 2,000 to 3,000 grubs.

The redeeming feature in the use of this method is that the pots act as a permanent trap, and after a bed has been thoroughly rid of the grub the pots can easily be shifted to other infested fields. Moreover, the pots need not be emptied oftener than two or three times a week, or until they become two-thirds filled with grubs. In most instances observed, when larvæ are thus confined they destroy each other, thus preventing the pots becoming filled or affording the larvæ a means of escape.

In fallow fields or in spaces between beds, larger pots may be used. Experiments were conducted by using 7-inch flowerpots in the ground in the same manner as described for the small pots (Pl. IX, A). The advantage in the use of the larger pots is that the contents need not be emptied. Sometimes, when rains occur, the pots become filled with water, which drowns the larvæ.

This method is the only one now known that can be safely used in saving a crop that is planted in an infested field. Except for the outlay in obtaining the pots and the labor required in setting them in the ground, there is no expense attached to this method.

THE V-SHAPED TROUGH METHOD.

- Trapping the grubs by constructing V-shaped troughs proved quite successful. (Pl. X; text fig. 7.) Owing to their size they can be

used only between beds of growing crops like lettuce, beets, parsley, turnips, celery, or in uncultivated fields. The method of procedure is to use boards 6 to 8 inches wide and of any length desired. These are placed in the ground in the form of a steep V, having the top edges of the board about half an inch below the surface of the ground. The boards can be made to overlap as shown in Plate X.

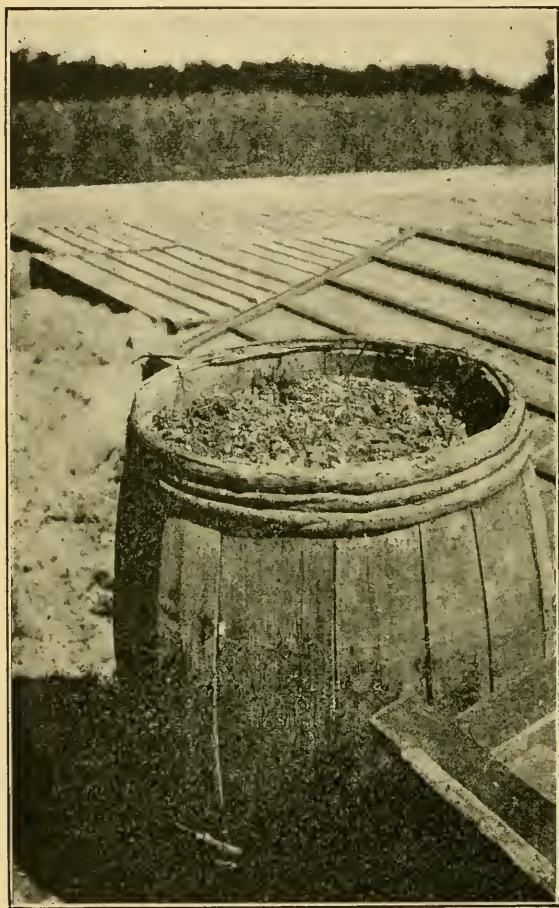


FIG. 7.—Barrel of grubs of green June beetle, estimated to contain 75,000 to 100,000, caught by trapping with troughs and flowerpots.

The only precaution necessary is to block out any cracks or open places where the larvæ are likely to escape. At each end of the trough a keg or bucket is sunk into the ground and the larvæ that fall in the trough usually crawl along the bottom and fall into the keg.

A trough constructed through the length of a field serves as a barrier, and grubs coming from either side of the trough are unable to pass without falling in. They are unable to crawl up the steep sides of the troughs; moreover, they seem to prefer to crawl along the bottom, with the result that they eventually fall into the kegs.

One of the large troughs thus con-

structed captured between 3,000 and 4,000 grubs in a single night. Estimates were made of the number of grubs captured on a 2-acre field containing 12 troughs, each 200 feet long, and within the short period of three weeks more than two 50-gallon barrels of grubs were trapped. Since there are approximately 400 grubs to each quart, and 200 quarts to a 50-gallon barrel, the number of grubs in a barrel would be 80,000, or about 160,000 grubs captured from a 2-acre field. (Fig. 7.)



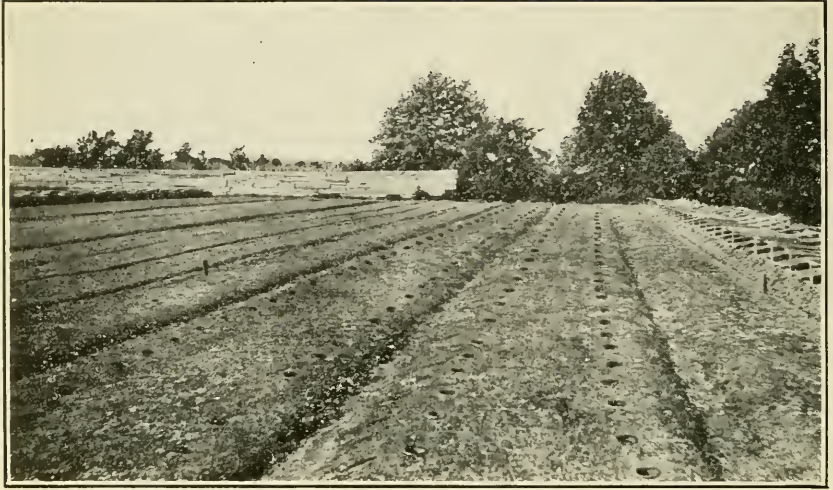
A



B

CAPTURING GRUBS OF GREEN JUNE BEETLE.

A, Method of picking up grubs by following a plow; *B*, boards placed over beds for trapping grubs.



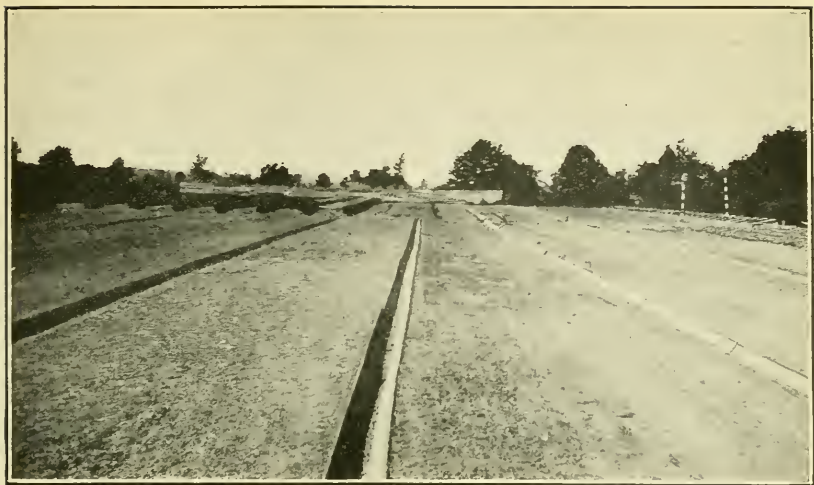
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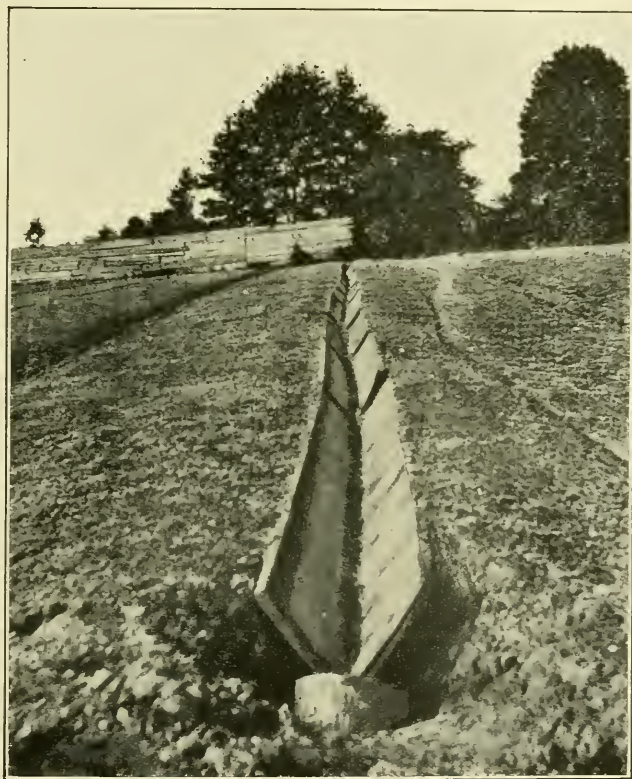
B

TRAPPING GRUBS OF GREEN JUNE BEETLE WITH FLOWERPOTS.

A, Field with 7-inch pots set about 3 feet apart; *B*, field in parsley with 3-inch pots set between rows, and 7-inch pots set in runways between beds.



A



B

TRAPPING GRUBS OF GREEN JUNE BEETLE.

A, Field set with V-shaped troughs 12 feet apart; B, the simple construction of a trough and keg for reception of captured grubs.

The adults of this species observed at Portsmouth, Va., during 1915 show a very considerable reduction in numbers, undoubtedly due to the large number of larvæ which had been captured in the fall of 1914.

SIMPLE TRAPPING METHODS.

The grubs have also been successfully captured in cold frames by the use of empty tomato cans. Mr. Trepass experimented on a larger scale on lawns and gardens at Glen Cove, Long Island, by setting boxes of the size of ordinary flats, about 3 inches deep, just below the surface, making the ground smooth around the boxes. During September he caught no less than 146 gallons, or nearly 240,000 of these insects.

GAS LIME.

Gas lime, which can be procured gratis for the expense of hauling, is well worthy of a trial. It should be applied in September or October for most vegetable crops; and for strawberry beds, potatoes, or vegetable crops, as soon as possible after the crop is made. One caution is to be observed, i. e., gas lime is dangerous to plant life; hence, it should be used experimentally on a small scale before employing it in entire fields.

INEFFECTIVE OR IMPRACTICAL METHODS.

A few remarks should be added in regard to what should be termed "ineffective methods"—remedies which have been suggested at times but which knowledge of the habits of the species show to be unworthy of trial, or which are impractical on account of their cost.

In 1895, Dr. J. B. Smith (25) claimed that kainit mixed with lime in the proportion of 1 ton of the former to 1,000 bushels of the latter proved fairly successful where tested in some parts of New Jersey. The high price of mineral fertilizers at the present time prohibits their use, otherwise they could be recommended in lieu of manure which, it is well known, serves to attract the female beetles for depositing their eggs.

Among the direct remedies which have been found most useful against the common white grubs (*Phyllophaga* et al.) there is scarcely one, with the possible exception of kerosene emulsion and carbon disulphid, which will be found effective against the grubs of this species.

PLOWING.

Plowing seems inapplicable in the case of these grubs, except possibly in late May or June, when they are in the prepupal stage or have recently pupated and are consequently soft and delicate. The plow-

ing should be deep and when possible should be followed by thorough disking.

Neither spring nor fall plowing would be practicable when the plants are growing, and at other times the grubs penetrate too deeply, to the depth of 18 to 30 inches, after the crops are gathered, for the plow to reach them. Naturally if the insects are capable of existing in humus, or in land from which crops have just been taken, plowing in summer would be of little value.

POULTRY AND HOGS.

Poultry of such kinds as chickens, ducks, and turkeys, are useful destroyers of white grubs. Their use for this particular grub, however, would obviously be limited to their following the plow when the grubs are most active. Since the latter are not exposed to any extent except at night, fowls would not be of much value. Swine are also known to be exceedingly fond of white grubs, and when allowed the run of fields infested by *Phyllophaga* larvæ destroy great numbers of them. It is problematical whether it would be possible to pasture hogs in areas infested by the grub of this species with any appreciable effect.

Everything considered, it would appear that the utility of domestic animals is confined to such times as after rainfall or in connection with flooding.

CROP ROTATION.

In regard to crop rotation it would be difficult to name a truck crop that could be profitably grown which this grub would not attack. Field and sweet corn, because of the woody nature of their stalks and roots, are not apt to suffer severe injury except when young. Cucurbits are not as a rule seriously affected by the larvæ, and in all probability pumpkin, squash, and melons are not so injured as to hinder growing them where these grubs are abundant. Onions are grown in rich land such as these grubs prefer, and as we have no record of injury it is quite possible that onions are distasteful to the grubs; the same might be true of pepper. Eggplant and potato, while occasionally attacked, are seldom reported severely injured.

In general it may be said that late crops, planted in June and afterward, will not suffer from this grub. All early seedlings, on the other hand, are subject to injury.

SUMMARY OF CONTROL MEASURES.

FOR BEETLES.

Hand methods are the best to employ for capturing the beetles as they occur on fruits. They may be captured in buckets or similar

receptacles containing a little water on which a film of kerosene is floating. A boy passes along the plants and knocks the beetles into the bucket. Sprays are impractical.

FOR GRUBS.

From experiments which were conducted during two seasons in tidewater Virginia against the larvæ of the green June beetle, the conclusion points to trapping as the best means of control in that region and probably in most others.

TRAPPING.

Flowerpots and V-shaped troughs have proved the most successful and inexpensive methods. Their simplicity and cheapness are factors in their favor. They also serve as permanent traps until a certain area is cleared of all grubs, and they can afterwards be shifted from one field to another. Where a crop has already been planted, the flowerpot method is the only one that can be safely used. In other situations where a trough can be placed, this method is the most advantageous and inexpensive.

KEROSENE EMULSION.

Experiments with kerosene emulsion indicate that success can be obtained when the grubs occur within 2 or 3 inches below the surface and when they begin to crawl above ground. In large areas the application is expensive but in more limited areas, as under sash, good results may be obtained with the emulsion at a strength of 1 to 10, using 3 gallons of liquid to a sash. The cost is approximately 2 or 3 cents a sash. There is no injury to foliage if carefully applied; parsley, a delicate plant, has not been harmed in the least.

Unless directions are carefully followed for the preparation and application and necessary precautions taken, kerosene emulsion is apt to fail. This, however, does not detract from the fact that properly applied it can be used quite successfully.

OTHER REMEDIES.

Poisoned baits such as have been used successfully against cutworms and grasshoppers have not been given a thorough test but are worthy of a trial. The same applies to lime and gas lime, because they have proved valuable against the common white grubs.

Collecting the grubs by mechanical measures is also of value, but, everything considered, is not as good as trapping measures which have been thoroughly tested.

Carbon disulphid will kill the insects and has been used successfully by Davis and Luginbill (45, p. 25) on putting greens, but it has not been thoroughly tested on truck farms. The same applies to the rotation of crops.

It should be remembered that other remedies which are applicable for common white grubs, such as plowing and the utilization of domestic animals as destroyers, are ineffective under ordinary circumstances.

GENERAL SUMMARY.

The green June beetle is a common and well-known insect in the eastern United States, from New Jersey and southern Illinois southward. It occurs also commonly on Long Island and in southern Connecticut.

It prefers a sandy or sandy loam soil, richly incorporated with humus, and for that reason is troublesome in many trucking sections of the country, particularly the sandy coast regions.

The larvæ, or grubs, injure vegetables of many kinds, particularly celery, parsley, lettuce, beets, turnips, carrots, parsnips, collards, sweet corn, and peas and beans in the seedling stage.

While there is evidence that the larvæ injure certain of these plants by severing the roots and young stalks, major injury is due to the upheaval of the soil around the plants, which disturbs the root system. Their constant burrowing near the surface in the fields and garden loosens the earth, causing it to dry out, which greatly retards and injures the plants' growth.

The grubs are the cause of extensive trouble on lawns and golf greens and do injury also to alfalfa, oats, and some other crops, including ornamental plants.

The beetles injure fruits of various kinds, especially grapes, peaches, apricots, and figs, and growing ears of corn, and feed also on the sap of trees.

There is only one generation or brood of this insect a year.

The beetles occur from the middle of June to September and are to be seen in greatest numbers from the middle of July to the middle of August, these periods varying somewhat according to location and temperature.

Eggs are deposited from 6 to 8 inches below the surface of the soil and hatch in from 10 to 15 days. After the first molt the larvæ feed nearer the surface of the soil. Larvæ become three-fourths grown by late fall, having molted twice. With the approach of cold weather, they go deeper into the ground—8 to 10, and even 30, inches below the surface—and continue inactive during the winter, except in mild winter localities where the grubs may be active at any time during warm spells. Early in spring, depending on locality,

the grubs again become active until the middle of May, when the larva makes a substantial cocoon, in which it transforms to the pupa. The pupal period lasts 15 to 20 days.

Many natural enemies of the grubs and beetles, such as birds and certain internal insect parasites and predacious insects, materially aid in the reduction of the pest. Of these, blackbirds, robins, and a large digger wasp are the most effective.

For the control of the grubs in cultivated fields, trapping with flowerpots or V-shaped troughs are the most successful. Poisoned baits, prepared in the same manner as for cutworms, scattered on lawns and cultivated fields late in the evening, are also valuable. Kerosene emulsion is an excellent remedy. Flooding is of value on golf links and lawns.

Hand methods are employed for capturing the beetles as they occur on fruits and for the larvæ on lawns and golf greens.

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PROFESSIONAL PAPER

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THE BEET LEAF-BEETLE.¹

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Truck-Crop Insect Investigations.

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INTRODUCTION.

In the Rocky Mountain States sugar beets are subject to attack by the beet leaf-beetle, known in some localities as the "alkali bug," and in others as the "French bug." The principal injury caused is due to the attack of the larvæ, although the beetles also inflict considerable damage, hundreds frequently being found on a single plant, which is entirely consumed or so injured that it shrivels and dies. (See Pl. I.)

Injurious attack first attracted attention during 1897 and 1898, when injuries were noted both in New Mexico and Colorado. Prior to that time this insect was not known to injure cultivated plants, having confined its attack to such weeds or wild plants as the sea-blites, Russian thistle, and saltbush.

DESCRIPTION.

THE ADULT.

This insect is related to the imported elm leaf-beetle,³ and is of similar appearance to that species in the larval, pupal, and adult stages, but it is considerably larger, and the beetle has a longer thorax, and is differently marked.

¹ *Monoxia puncticollis* Say.; order Coleoptera, family Chrysomelidae.

² Deceased.

³ *Galerucella luteola* Müll.

The beetle is variable in color and especially in markings, and in size, the length being from one-fourth to one-third inch. It is of oblong form, narrowing in front, and the color varies from pale yellow or buff to nearly black, while the elytra or wing-covers are uniformly yellowish or darker, but usually more or less distinctly striped with black. The beet-feeding form most commonly found is illustrated in figure 1, *a*.

The technical description by Dr. Geo. H. Horn (4)⁴ follows:

THE GENUS *MONOXIA* LEC.

Head oval, moderately convex, not deeply inserted, front feebly or not impressed. Antennæ filiform, not longer than half the body, third joint as long as the first, fourth longer than the second, joints 6-10 subequal in length; labrum moderately prominent, truncate with rounded angles; maxillary palpi

moderately stout, second and third joints obconical, the terminal conical and more slender; prothorax transverse, widest at base, except in *sordida*; scutellum oval at tip; elytra oblong, scarcely broader behind the humeri, closely and irregularly punctured, the side margin not prominent; epipleuræ narrow, but extending nearly to the tips of the elytra; prosternum entirely obliterated between the coxæ, the coxal cavities open behind. Legs moderate, the anterior tibiæ indistinctly grooved on the outer side, tibiæ without terminal spurs; tarsi shorter than the tibiæ, the first joint as long as the next two; claws dissimilar in the sexes, finely bifid in the male, absolutely simple in the female.

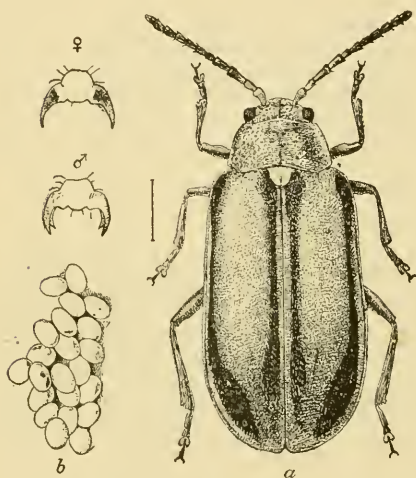


FIG. 1.—Western beet leaf-beetle (*Monoxia puncticollis*): *a*, beetle; *b*, eggs; ♀, claws of legs of female; ♂, ditto of male. *a*, much enlarged, *b*, more enlarged. ♀ ♂ highly magnified.

MONOXIA PUNCTICOLLIS Say.

Form oblong, narrowed in front; surface finely pubescent, color vari-

able from pale yellow to entirely black, or with the elytra vittate. Antennæ variable in color from entirely black to pale, generally with the outer half dark, the base pale, fifth joint always shorter than the fourth or sixth. Head coarsely and closely punctate. Thorax not quite twice as wide at base as long at middle, broader at base than apex, sides freely arcuate, base broadly emarginate at middle, oblique each side, hind angles distinct; disc usually irregular, with broad, vague depressions each side, so that at times the sides of the thorax appear deplanate, a vague median impressed line, surface very coarsely and irregularly punctate; elytra closely punctate and finely pubescent, the punctures coarser near the base, fine and closer toward the sides and apex. Body beneath finely sparsely punctate and pubescent. Length .27-.34 inches; 7-8.5 mm.

Male. Claws [fig. 1, ♂] finely bifid at tip; last ventral segment obtuse, with a short median linear impression near the apex.

⁴ Figures (italic) in parenthesis refer to "Literature cited," p. 23.

Female. Claws [fig. 1, ♀] absolutely simple; last ventral obtuse, with a small notch at middle, from which proceeds a slight impression or a smooth line. (Horn).

SYNONYMY.

The following forms are considered synonyms:

Galeruca morosa Lec., Rept. Pac. R. R. Expl., p. 70.

Galeruca maritima Lec., Proc. Acad. Nat. Sci. Phila., 1865, p. 218, 219.

Galeruca crosa Lec., Trans. Amer. Ent. Soc., v. 12, 1885, p. 25.

THE EGG.

The egg (fig. 1, *b*) is variable rounded oval in shape, light orange yellow when first laid, changing to dull brownish gray; strongly convex above and moderately flattened on the underside where attached to a leaf. The surface is minutely and deeply reticulated or pitted, a septagonal arrangement predominating, although hexagons also occur. The length is 0.8–0.9 mm. and the width 0.6–0.7 mm.

The eggs are deposited side by side, usually on end, and closely together in irregular clusters—not infrequently in two layers, some laid on top of others—varying in number from 2 or 3 to 50, with an average of about 20 eggs in each cluster. They are laid on either the upper or lower side of the leaves of beets and more often on other larval food plants. (See Pl. II.)

THE YOUNG LARVA.

The young larva when hatched measures about 1.5 mm. and differs from the mature form in having a more prominent head, a dark brown thoracic plate on shield, and in being of a dull gray color, the tuberculate areas being less conspicuous, showing as darker brown. The legs are relatively more prominent and the hairs or spines with which the tubercles are armed are longer.

THE MATURE LARVA.

The mature larva (fig. 2) resembles in general contour, both as seen from above and from the side, that of *Galerucella*. It is nearly uniform dark olive brown in color, spotted with piliferous tubercles, which are more or less rounded, rather pale yellow and strongly marked. They are arranged in somewhat irregular rows, as shown in the illustration, those on the dorsal surface of the abdominal segments coalescing near their centers, forming transverse bands. The head is moderately shining black and portions of the legs are

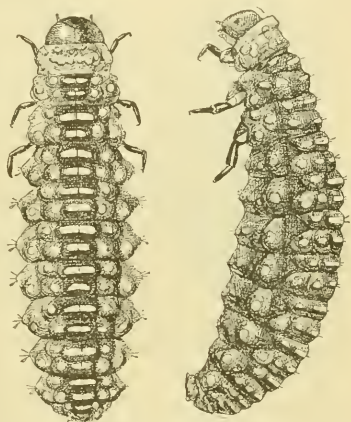


FIG. 2.—Beet leaf-beetle: Dorsal view of larva at left; profile view at right. Highly magnified.

of the same color. The hairs with which the body is very sparsely clothed are of two kinds, pointed and truncate, some being pale and some dark in color, all being rather short. The head is about half as wide as the first thoracic segment and the body gradually widens to the third and fourth abdominal segments, and then tapers gradually toward the anal extremity, and the last segment is rather narrow. The segmentation is strongly marked and the tubercles on the sides prominent. The legs are long and somewhat slender.

The length in somewhat contracted natural position is about 8.5–9.03 mm. and the greatest width 2.8–3 mm.

THE PUPA.

The pupa (fig. 3) is of the usual chrysomelid form, nearly twice as long as wide, pale yellowish in color, the head prominent, bent downward on the thorax, with the legs folded so that the tarsi are in a nearly parallel line. The wing-pads are rather long and the abdominal segments are noticeable for the lateral processes, each of which bears a short spine-like hair.

The length is 6.5–8 mm. and the width 3.5–4 mm.

DISTRIBUTION.

The beet leaf-beetle occurs along the Atlantic seaboard from Massachusetts to Florida, in California near the seacoast, and in the alkaline regions of Colorado, Utah, and New Mexico. In its eastern occurrence it is maritime, being found very little inland from the States mentioned. The distribution is shown in the map, figure 4.

The maritime origin of the species is evidenced by its occurrence in the East along the entire Atlantic coast from New England to the Gulf of Mexico. It is seldom, if ever, found far inland in that region. In the West it occurs in California near the seacoast and also in the alkaline regions of Arizona, New Mexico, Colorado, Utah, and Montana. In its distribution it resembles *Cicindela lepida* Dej., a white form of tiger beetle inhabiting the alkaline or saline, white, sandy soil left by the recession of the sea water which formerly covered this region. The writer is inclined to believe that the coastal forms are at least subspecies or races and that a third form which occurs in Florida, in Kansas, and in southern Texas constitutes still another subspecies.

A single adult of this species was collected at Wichita, Kans., April 24, 1917, by Mr. F. M. Wadley, Bureau of Entomology. It is of the normally injurious form and it is not improbable that the species may have a somewhat general distribution in Kansas, but it

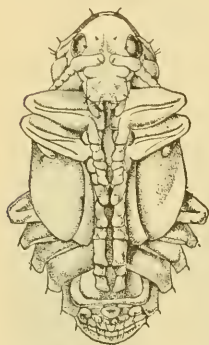


FIG. 3.—Beet leaf-beetle: Pupa, much enlarged.

must be somewhat local as regards abundance; in other words, what we commonly term rare.

Only the so-considered subspecies or normal type occurring in the Middle West from Arizona and New Mexico to Montana is destructive to sugar beet, although in one instance report of attack to beets at Brownsville, Tex., was noted. While the localities indicated on the map show injuries only in six States, it is readily seen that injury is apt to take place in neighboring States; e. g., Wyoming, western Nebraska, Kansas, Oklahoma, and Texas, and perhaps eastern Nevada. From what is known of this species it seems probable that it is not one of the numerous pests which are constantly on the increase and which are enlarging their injurious distribution, but, on

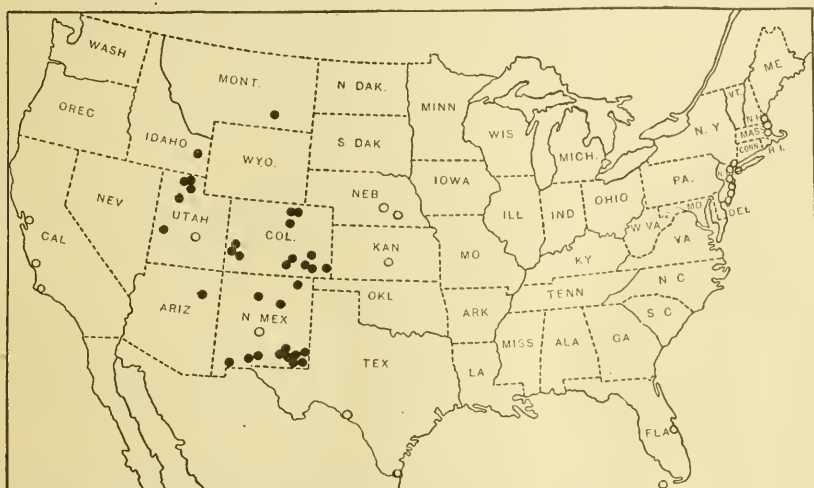


FIG. 4.—Map showing distribution of beet leaf-beetle. Large dots show injurious distribution; circles, innoxious localities.

the contrary, it may, in the course of time, especially if remedial measures are adopted, rather decrease its injurious range than otherwise, or at least decrease as a pest.

REPORTS OF INJURIES.

Under date of January 4, 1898, Mr. Henry C. Barron, Hagerman, N. Mex., sent specimens of the beet leaf-beetle with statement that it was doing serious injury to the sugar-beet crop in that locality. Its presence was not noticed until the year 1897. A few of the beetles, locally known as "French bugs," were found at that time by digging in the earth by the side of a beet to the depth of about 6 inches. Neither eggs nor larvæ were to be found at this time. The correspondent stated that the beetles lay their eggs on the underside of a leaf, that they hatch in about 6 days, and that the young larvæ commence feeding at once and continue for 9 or 10 days, when they

dig their way into the ground and a few days later come forth as beetles. The principal damage it was noted was due to the larvæ, hundreds of which often occurred on a single plant, which was either consumed or apparently so injured that it shriveled and died.

During 1902 and 1903 this species was reported injurious to sugar beets by Mr. W. K. Winterhalter, Rocky Ford, Colo. May 7, 1902, he wrote that where the beetles had appeared they kept the leaves eaten down to such an extent that the beet was unable to make any growth. They were most numerous on very warm, loose land, rich in lime, and a rapid increase under the then favorable climatic conditions was anticipated. They were gregarious, occurring "in swarms like blister beetles." Later it was reported that while the beetles had not done extensive damage, they had prevented beets from growing in several fields through their continual inroads on the foliage. In one instance 5 acres had to be replanted. After the beets were irrigated they grew more rapidly and thus kept ahead of the beetles and serious damage was apparently averted for that season.

August 27, 1904, Mr. S. I. Borton, Lamar, Colo., sent sugar-beet leaves badly injured by the insect with living specimens of the beetle. September 26, Mr. H. Timothy, Greeley, Colo., wrote that about May 15 this species, the so-called "alkali bug," was very destructive to sugar beet, working almost entirely on alkali land. The insect was described as similar in shape and size to the Colorado potato "bug," yellowish with black stripes, and with a hard shell. This species was also observed in 1904 by Prof. E. G. Titus on sugar beet at Fort Collins, Greeley, Longmont, Grand Junction, and Rocky Ford, Colo.

May 26, 1905, Mr. J. H. Windfelder, manager of the National Sugar Manufacturing Co., Sugar City, Colo., sent beetles and larvæ observed on young sugar beet. They proved very destructive, destroying the young beets down to the ground. They were found in an area that was somewhat seepy or wet, and, although they spread beyond this area, they did the most damage adjacent thereto.

June 30, 1909, Mr. Harry B. Shaw, at that time engaged in sugar-beet investigations for the Bureau of Plant Industry, sent specimens collected on sugar beet at Thatcher, Utah, growing on the margin of fields close to alkaline ground in which grew "salt-grass" (*Atriplex* sp.) and some other weeds. At that time the insects were migrating to the beets and eating them to the ground, although the beets were then of considerable size. This species was also reported by Mr. Shaw attacking beets and *Dondia* at Garland, Utah, August 15.

June 14, 1910, injury was reported to young beets at Manzanola, Colo., by Mr. W. W. Spencer. He found it in beets growing near sloughs and a considerable number on lamb's-quarters.

July 5, 1910, numerous adults and egg clusters were observed by Mr. D. K. McMillan in a beet field a mile southwest of Rocky Ford, Colo. They were also working on Russian thistle growing along a ditch, together with larvæ about a week old. This locality is near a large "alkali spot" caused by seepage. Adults were very abundant there the previous fall and many came through the winter under rubbish. During the week following, beet leaves were considerably eaten around the edges by the beetles. The species, it was surmised, would be likely to cause considerable damage in the field at this point during the next few weeks if it were not checked by spraying. August 9 Mr. McMillan reported all stages very numerous in the alkali flat 2 miles south of town on weeds along the roadside and on sugar beets at Rocky Ford, Colo. Pupæ were not difficult to find in the soil around beet plants and were located from one-half inch to 2 inches beneath the surface of the ground, which was a sandy loam. Numerous egg masses were found on wild plants which had been defoliated. Fifty adults were found on some plants and on others fully 100 larvæ.

In 1913 it was reported injurious to sugar beet at Artesia, N. Mex., August 4, by Mr. R. W. Bruce.

July 17, 1916, Prof. D. E. Merrill, State College, N. Mex., reported this species feeding on sugar beets.

FOOD PLANTS.

The adults have been observed feeding on the following varieties of beet (*Beta vulgaris*): Sugar beet, garden or table beet, mangel-wurzel, and Swiss chard. They have also been found on spinach (*Spinacia oleracea*), lamb's-quarters (*Chenopodium album*), sea-blite (*Dondia erecta*, *americana*, *linearis*, *multiflora*, and *depressa*), Russian thistle (*Salsola pestifer*), saltwort (*S. kali*), saltbush (*Atriplex argentea*, *patula*, and *hastata*), sea purslane (*Sesuvium sessile*) and pigweed (*Amaranthus retroflexus*). Some of these host plants are shown in Plates II to V.

Lamb's-quarters, sea-blite, and sugar beet are the favorite food plants of the beetle; Russian thistle and sea purslane are readily eaten in early spring when other food is comparatively scarce, but table beets, mangel-wurzel, spinach, and Swiss chard are more rarely injured, although relished by the beetles which occur on them by chance infestation. Salt-bush and pigweed are less popular and seldom attacked.

The larvæ are still more restricted in their choice of food. They have been observed feeding on sea-blite, lamb's-quarters, Russian thistle, and sugar beet. Sea-blite (Pl. VI, D), and lamb's-quarters (Pl. VI, C) are decidedly the favorites and are eaten in preference to all other plants. Sea-blite occurs in densely growing areas and by

far the greatest number of larvæ usually develop on it. Large areas of this plant, acres in extent, are often killed by the insects. The dead plants turn black and, at a distance, appear as though injured by fire. The spikelike leaves of young Russian thistle are eaten by the larvæ but are not a favorite food. While large numbers of larvæ frequently develop on sugar beet, this happens as a general rule only in the event of a scarcity of the favorite natural food plants. Larvæ are sometimes so abundant on sea-blite and lamb's-quarters about the margins of beet fields that the plants are killed (Pl. VI, C, D) and become dry, causing the partly-grown larvæ to crawl into the beet fields and complete their development on the beets.

Eggs are occasionally deposited on sea purslane and on some other weeds, but the larvæ have not been observed developing on these plants.

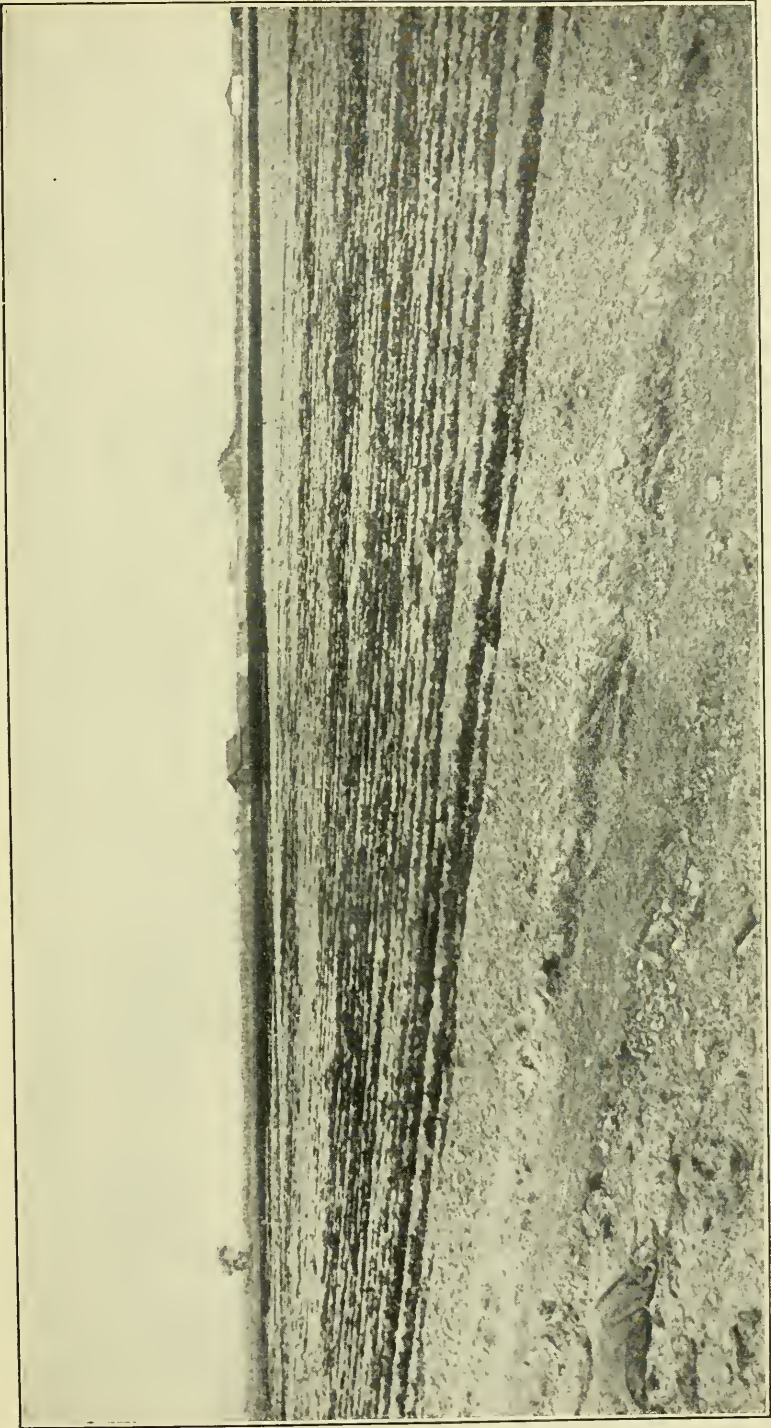
OCURRENCE AND EXTENT OF INJURY.

The beet leaf-beetle, under natural conditions, lives upon weeds growing on land which, in many cases, is too highly charged with alkali to support cultivated crops. This waste land occurs throughout the upper Arkansas Valley in Colorado in low portions where excessive quantities of alkali have accumulated through natural drainage or by seepage from the irrigation ditches. These alkali areas vary in extent from a few square rods to many acres. Some of the alkali land has been partially or wholly reclaimed by tile drainage and, in many cases, the worst alkali spots adjoin or are surrounded by highly cultivated land. (See Pls. IV, V.)

Sugar beets and sorghum, being particularly resistant to alkali, are frequently grown on land which is too "salty" to produce profitable crops of less resistant plants. Sorghum is not injured but the foliage of sugar beet is well liked by the beetles, and when this crop is grown on or near the alkali areas it is frequently severely damaged.

As long as there is a supply of the natural food plants available little damage is done to sugar beets. In the spring, before the weeds become abundant, the overwintered beetles, and more rarely the larvæ, may infest small, young beets and completely destroy them. Later the insects may develop in such enormous numbers that many of the weeds are killed and they may then resort to sugar beets for food. Many hundreds of acres of beets are infested every year. (See Pl. I.)

The injury resulting from infestation varies greatly, depending upon the abundance of the insects and the size of the infested beets. Small beets may be completely destroyed, while larger plants may be partially or completely defoliated and checked in growth. (See Pl. VI, A, B; Pls. VII-IX.) Usually the acreage that is destroyed is

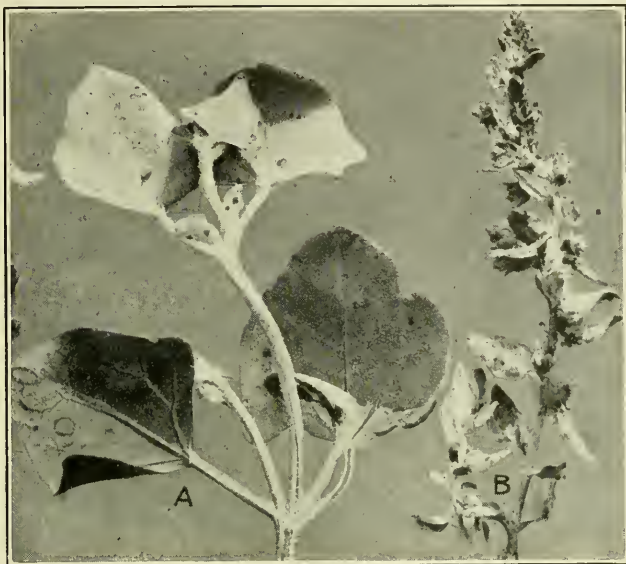


SUGAR-BEET FIELD SHOWING INJURY BY BEET LEAF-BEETLE (*MONOXIA PUNCTICOLLIS*).



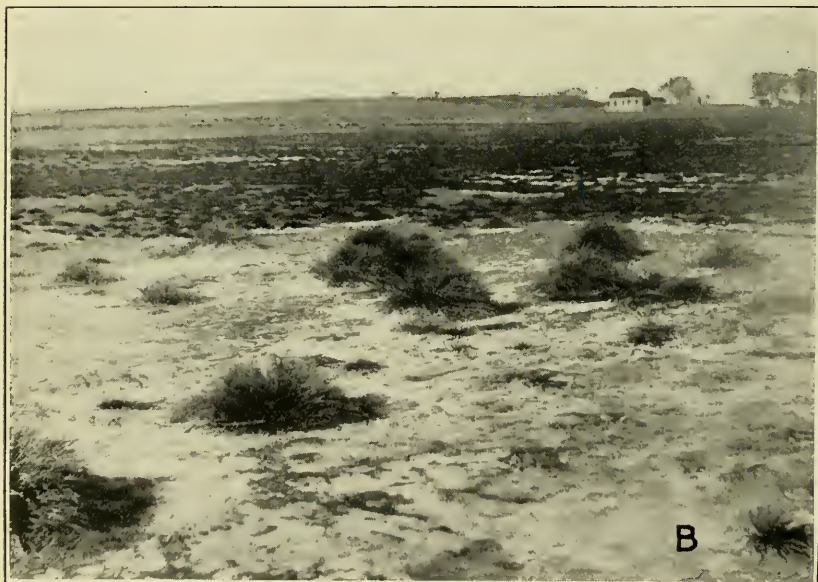
OVIPOSITION OF BEET LEAF-BEETLE.

A, Group of dry stems of *Atriplex* sp., a favorite place for egg-laying of beet leaf-beetle (*Monoxia puncticollis*). *B*, Sea-blite plants showing eggs of beet leaf-beetle. *C*, Sugar-beet leaf showing eggs of beetle. About natural size.



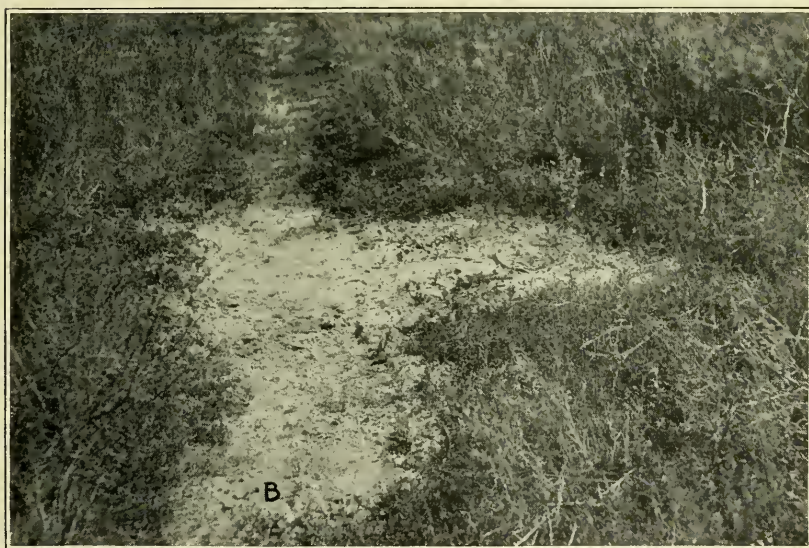
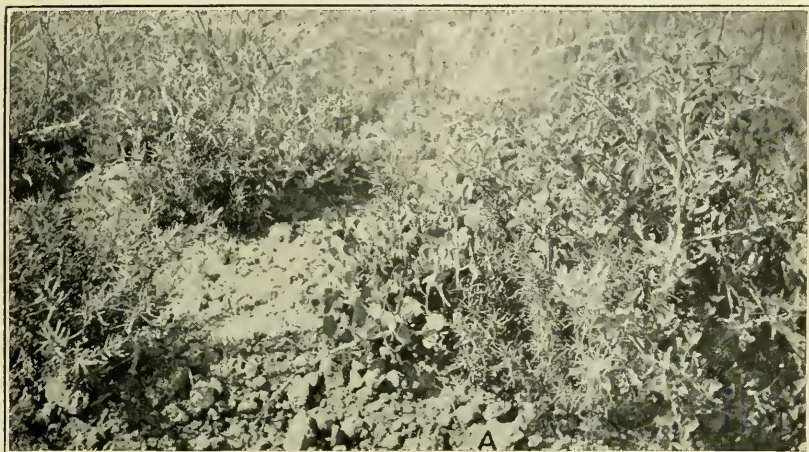
HOST PLANTS OF BEET LEAF-BEETLE (*MONOXIA PUNCTICOLLIS*).

A, B, Salt-bush (*Atriplex* sp. and *Atriplex patula*). C, Saltwort (*Salsola kali*). D, Russian thistle (*Salsola pestifer*).



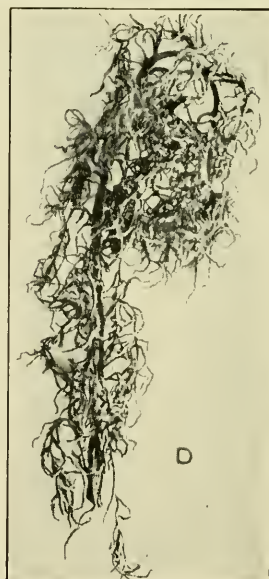
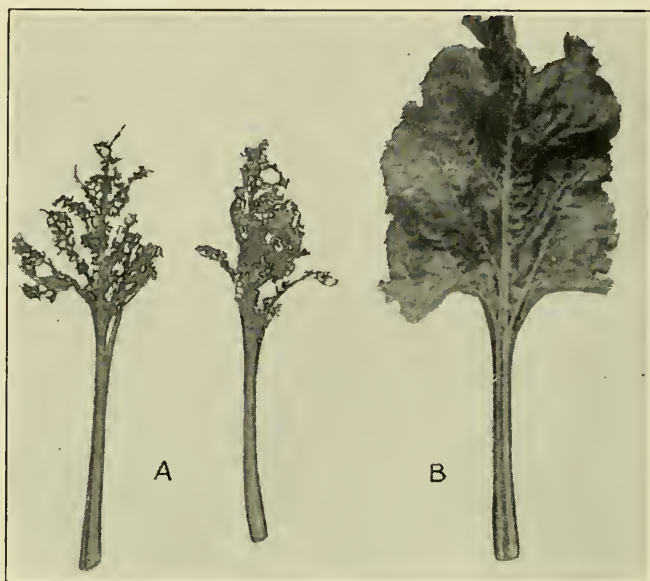
HABITAT OF BEET LEAF-BEETLE.

A, Alkali area overgrown with sea-blite, furnishing natural food for beet leaf-beetle. *B*, Typical alkali area showing grass tufts under which beet leaf-beetle hibernates.



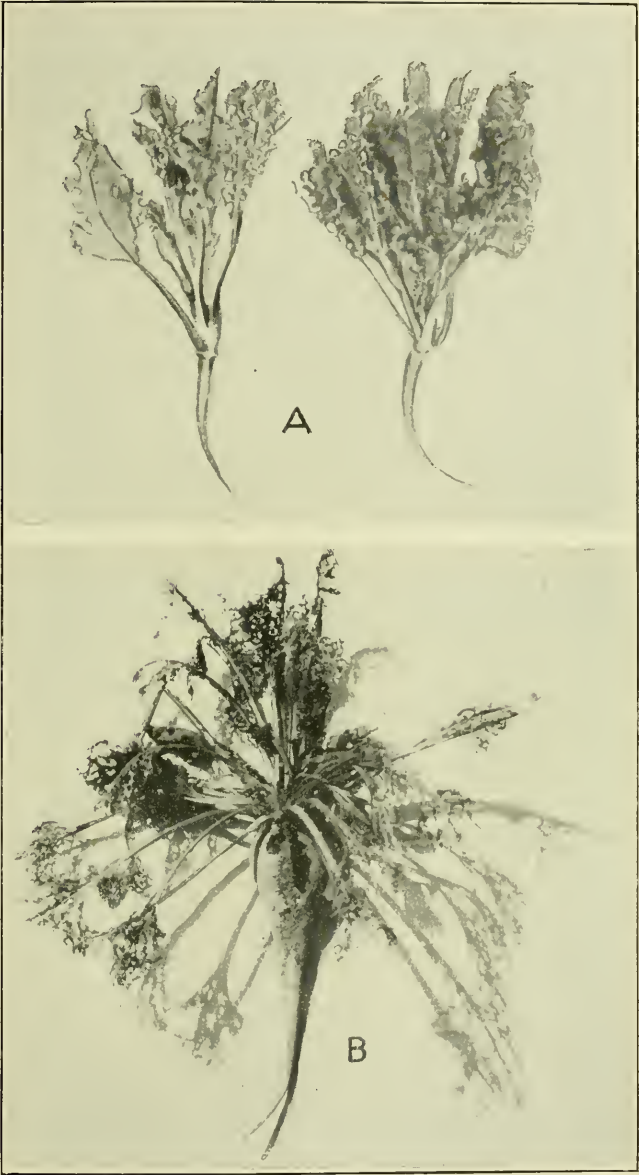
HABITAT OF BEET LEAF-BEETLE.

A, Abundance of eggs found on sea-blite (*Dondia* sp.) and salt-bush (*Atriplex hastata*). B, Habitat in alkali flat contiguous to beet fields; bare spot near center is white with alkali.



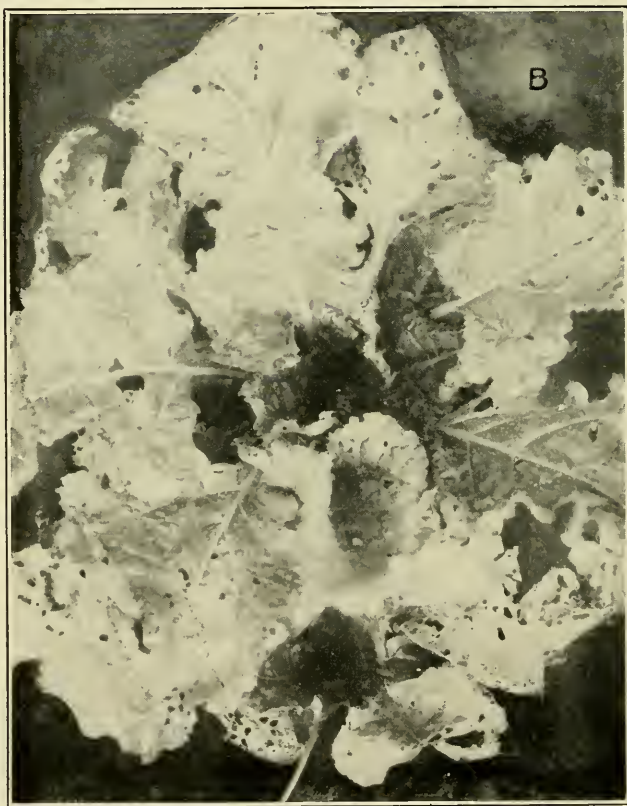
FOOD PLANTS OF BEET LEAF-BEETLE.

A, Sugar-beet leaves riddled by beet leaf-beetle. *B*, A less injured leaf. *C*, Lamb's-quarters killed by larvæ of beet leaf-beetle. *D*, Sea-blite killed by same.



WORK OF BEET LEAF-BEETLE.

A, Small sugar-beet plants riddled by adults of beet leaf-beetle. *B*, Larger plant defoliated by beetles.



WORK OF BEET LEAF-BEETLE.

A, Sugar beet in beet field injured by beet leaf-beetle, all outer leaves riddled. *B*, Sugar-beet top showing injury by beet leaf-beetle around margins of outer leaves.



WORK OF BEET LEAF-BEETLE.

A, Sugar-beet leaf skeletonized by beet leaf-beetle; beetle natural size below. *B*, Sugar-beet seed stems entirely denuded by beet leaf-beetle.

small, although in some years, in 1909 for example, 200 acres of sugar beets in the Arkansas Valley were observed that were literally "wiped out." As a rule, the most noticeable loss resulting from infestation is a reduction in sugar content which follows defoliation. Owing to various other factors which tend to increase or decrease the sugar in the beets, it is impossible to state definitely how much loss may be expected from defoliation by the beet leaf-beetle. Comparative analyses have indicated, however, that injury varying from partial to complete defoliation during August may result in a loss of from 5 to 25 per cent of sugar.

During the summer of 1912 Miss V. W. Pool, of the Bureau of Plant Industry, discovered that the beet leaf-beetle may serve as an agent in distributing the spores of the leaf-spot disease (*Cercospora beticola* Sacc.). July 31 Miss Pool collected four beetles from sugar beets at Rocky Ford and confined them for a few minutes in a culture plate of bean media. One colony of *Cercospora* developed in this plate.

In feeding on sugar beets the beetles cut large irregular holes (Pl. VIII; Pl. IX, A) through the leaves. The older, outer leaves are preferred, and when riddled the portions between the holes turn brown and fall away, leaving nothing except the petioles and larger veins. As previously mentioned, the insects prefer certain weeds as food, and as a rule spread to the beets when the favorite weeds are scarce or exhausted. As a result the beets growing nearest the weeds are the first to become infested.

The beetles are strong fliers, and during July and August may spread pretty generally over beets growing near alkali areas. A field of beets may be generally infested, but almost invariably there will be certain areas, varying from 6 to 20 or more feet in diameter, where the beetles congregate in large numbers. As many as 200 or 300 beetles may occur on single large beets, and the foliage is naturally more quickly destroyed than on less badly infested plants. As a result these areas are usually conspicuous in infested fields.

The larvæ feed in exposed positions on the upper or lower sides of the leaves. On thick-leaved plants they may eat pits in the leaves without cutting through, but on thin-leaved plants they usually cut irregular holes entirely through the leaves.

When mature the larvæ leave the plants and burrow into the soil to a depth of a half inch to 2 inches and form cells by wriggling about. The soft, yellow pupæ are formed in these cells. The adults develop in the cells and usually remain in them for two or three days. When they emerge they are dull yellow and soft. They commence to feed at once and become hardened and attain full color within a few days.

LIFE HISTORY.

In the Arkansas Valley of Colorado and in regions having a similar temperature, two full generations or broods and a partial third generation occur each year.

The adult passes through the winter on the surface of the ground on or about the alkali areas, under tufts of grass, heaps of dead weeds, and other rubbish. The favorite location for hibernation is under tufts of "tickle grass" (*Panicum capillare*), which occur abundantly on alkali areas (Pls. IV, V). Under natural conditions the majority of the beetles will congregate for hibernation under grass tufts or under weeds on these areas, a habit of which we may take advantage in controlling the beetles as will be explained later on.

The beetles issue from hibernation during March and early April, the exact time depending on temperature. The earliest date of emergence noted at Rocky Ford, Colo., was March 12 and the latest April 10. Usually the majority of beetles issue during the last days of March and the first days of April. The time of emergence corresponds with the appearance of young Russian thistles, sea-blite, and lamb's-quarters. On these plants the beetles feed and mate and within a short time commence to deposit eggs (Pl. II). The first eggs may be laid during the last days of March and through April, but ordinarily the bulk of the eggs is not deposited until the latter part of April or in May. The development of the first eggs and larvæ is slow. Under ordinary conditions the majority of the beetles of the first generation develop between the last days of May and the middle of June.

The beetles of this generation usually feed for 10 days or two weeks and then deposit eggs for the second generation. The bulk of the eggs is deposited during the latter part of June and through July and the majority of the beetles develop during the latter part of July and early August. During the remainder of the summer the beetles occupy the greater portion of their time in feeding. A few eggs are usually deposited from which the beetles of a partial third generation develop in September or the first days of October. As a rule, the number of beetles of the third generation is small and of slight importance, although occasionally a considerable number may develop about the middle of September.

In general, reproduction occurs from the last days of March until the first days of October, with the period of greatest development between the middle of May and the middle of August.

During September and early October the beetles leave their food plants and go into hibernation. As a rule, the greatest number begin hibernation between September 10 and 20. During bright sunny

days in September hundreds of the beetles may be seen flying from the beet fields in search of hibernating quarters, which they usually succeed in finding before the first severe frosts.

Practically all overwintered beetles die during the latter part of May or in June, although occasional individuals may live until the first days of July, from which it may be seen that the beetles of the first generation live a full year.

REARING RECORDS.

April 6 a mating pair of overwintered beetles was placed in a rearing cage containing growing plants of *Dondia erecta*, one of the sea-blites. The first eggs were deposited April 9. A second cluster of eggs was deposited April 11. The record is as follows:

First generation.

April 6	Beetles collected.
April 11	Eggs deposited.
April 29	Larvæ hatched.
May 23	Larvæ reached maturity.
May 28	First pupæ formed.
June 6	First adults developed.

From the foregoing record the developmental periods are as follows:

	Days.
Egg period	18
Larval period	29
Pupal period	9
Total period from egg to adult	56

The beetles which issued June 6 were placed in a separate cage and supplied with lamb's-quarters (*Chenopodium album*) as food. The record is as follows:

Second generation.

June 6	Beetles developed.
June 17	First eggs deposited.
June 25	First larvæ hatched.
July 9	First larvæ reached maturity.
July 14	First pupæ formed.
July 22	First adults developed.

From the foregoing record the periods are as follows:

	Days.
Incubation period	8
Larval period	19
Pupal period	8
Total period from egg to adult	35

The beetles of the second generation, as well as those of the first, fed heartily throughout the remainder of the season on the foliage

of sugar beet and lamb's-quarters, but no eggs for a third generation were deposited. All went into hibernation before the middle of September.

The dates of emergence and other dates given in the foregoing records tally almost to a day with those made in independent field records during another season.

Every year a few beetles of a partial third generation are produced. This is shown by the following records:

On May 17 several large larvæ were collected in the field from lamb's-quarters and placed in a rearing cage.

First generation.

May 17	-----	Larvæ collected.
May 19	-----	Larvæ reached maturity.
May 23	-----	First pupæ formed.
May 30	-----	First adults developed.

As the larvæ were collected in the field, the foregoing record is not complete. The pupal period, however, was 7 days. A pair of these beetles mated June 14 and were placed in a separate cage. The record is as follows:

Second Generation.

May 30	-----	Beetles developed.
June 14	-----	Beetles mated.
July 11	-----	First eggs deposited.
July 20	-----	First larvæ hatched.
July 29	-----	First larvæ reached maturity.
August 3	-----	First pupæ formed.
August 12	-----	First adults developed.

From the foregoing record the periods are as follows:

	Days.
Incubation period	9
Larval period	14
Pupal period	9
Total period from egg to adult	32

The beetles, 15 in number, which developed August 3 were confined in one cage. August 21 a single cluster of 17 eggs was deposited but none thereafter, and all the beetles went into hibernation during early September. The record for these 17 eggs is as follows:

Third generation.

August 12	-----	Beetles developed.
August 21	-----	First eggs deposited.
August 27	-----	Larvæ hatched.
September 10	-----	Larvæ reached maturity.
September 20	-----	First pupæ formed.
October 1	-----	The adults developed.

From the foregoing record the periods are as follows:

	Days.
Incubation period.....	6
Larval period.....	24
Pupal period.....	11
Total period from egg to adult.....	41

It will be seen that the adults of the third generation developed October 1. This was considerably later than the date when the majority of the beetles of the first and second generations, both in the field and laboratory, went into hibernation. The beetles of the third generation fed for a day or two and then went into winter quarters.

EGG-LAYING RECORDS.

March 21 several overwintered beetles, which were then on the wing, were captured and confined in a cage with young Russian thistle for food. March 23 a pair of these beetles mated and were placed in a separate cage. By March 29 the female's abdomen was noticeably distended with eggs. The record is as follows:

Eggs deposited.

April 2.....	7
April 9.....	34
April 12.....	40
April 18.....	35
April 23.....	5
May 15.....	23
May 17.....	21
May 23.....	30
June 10.....	6
June 15.....	9
June 23.....	5
Total number of eggs.....	215

The male died June 25 and the female July 7. These beetles were observed copulating March 23, 25, 26, 27, 31; April 1, 2, 4, 5, 6, 7, 8, 10, 11, 12, 13, 24, 26, 27, 28; May 7, 11, and 13. It is interesting to note that such frequent mating is not necessary to insure the fertility of the eggs. This is demonstrated by the following records:

March 24 a female, with abdomen noticeably distended with eggs, was captured in the field and confined in a cage without a male. Eggs were deposited as follows:

Eggs deposited.

March 27.....	33
April 2.....	4
April 5.....	6
April 9.....	25

April 10.....	29
April 12.....	20
April 14.....	15
April 17.....	30
April 19.....	29
April 22.....	35
April 26.....	9
April 30.....	31
May 7.....	22
Total number of eggs deposited.....	288

This beetle died May 15. As previously noted, she was confined without a mate, but had evidently been impregnated previous to March 24, as all her eggs hatched.

On May 9, 1911, an overwintered female was captured in the field and confined in a cage without a male. Eggs were deposited as follows:

Eggs deposited.

May 10.....	14
May 11.....	18
May 12-14.....	32
May 15.....	20
May 16.....	13
May 17-18.....	40
May 19.....	15
May 23.....	10
May 24.....	25
May 25.....	21
May 27.....	11
May 29.....	16
May 31.....	32
June 2.....	22
June 3.....	12
June 4.....	17
June 5.....	8
June 6-7.....	58
June 8-9.....	26
June 10.....	11
June 12.....	6
June 14.....	6
June 19.....	7
Total number of eggs.....	440

HISTORY.

The beet leaf-beetle was first described by Thomas Say (1) in 1824 under the name of *Galleruca puncticollis*, from Mississippi and Arkansas.

In 1838 Harris (2, p. 101) made what is evidently the first mention of the habits of this species, stating, while writing of the striped cucumber beetle,⁴ that "the habits are presumed to be the same as those of *Galeruca puncticollis*, which is found in profusion on the common *Salsola*. The larvæ of this species live in the earth and feed on the roots of *Salsola*, and do not leave the earth until they become perfect insects." The food plant mentioned is undoubtedly right, but the statement that the larvæ feed on the roots is erroneous and was doubtless inspired by the finding of larvæ prior to pupation in the earth about the roots.

In 1865 (3) the species was redescribed under the name of *Galeruca maritima* by LeConte, who stated that it was abundant from New York to Florida.

In 1893 Dr. G. H. Horn (4), in his monograph of the Galerucini, redescribed the species, placing it in the genus *Monoxia*, characterizing the genus and furnishing a list of synonyms and varieties with a consideration of the distribution.

The beet leaf-beetle is a comparatively new pest. The first records of injurious attack to cultivated crops were in 1898. In that year Dr. Wm. P. Headden (5) reported that the species had been plentiful on July 3 of 1897, and was doing considerable damage to sugar beet at Fort Collins, Colo. At that date the beets were sprayed with Paris green at the rate of 1 pound to 50 gallons of water, which gave the best results of any insecticide tried. The same year the senior author (6) recorded a simultaneous infestation to sugar beet, at Hagerman, N. Mex., in 1897, and gave notes on the insect's habits and history.

In 1900 Messrs. Forbes and Hart (7, p. 475-476) gave a brief account of the species in a comprehensive bulletin on the economic entomology of the sugar beet.

In 1902 Prof. C. P. Gillette (8) reviewed the previous history of the species and reported attack to sugar beets at Fort Collins, Colo., giving notes on the insect's life history and habits as it occurred in that region. It is recommended that in order to prevent injury to beets, alkali ground be avoided for planting purposes. This account is illustrated by a plate showing the eggs, larvæ, beetle, and injury.

In 1903 the senior author (9) published some additional notes in regard to this species, reporting injury to beets at Rocky Ford, Colo., in 1902, and furnishing descriptions of the egg and of the larva, with original illustrations of these and of the beetle. The same year he (10; 11, p. 9-11) published a summarized account of the species, followed by a condensed report (12).

⁴ *Diabrotica vittata* Fab.

In 1906 Prof. R. A. Cooley (13) mentioned attack to beets at Billings, Mont.

In 1912 and in 1918 summarized popular economic accounts were published by Messrs. Sanderson (14, p. 337-339) and Crosby and Leonard (15, p. 95-96).

NATURAL ENEMIES.

LADYBIRD BEETLES.

Fortunately the beet leaf-beetle has a goodly number of natural enemies. Among the most useful are the convergent ladybird (*Hippodamia convergens* Guér.), the sinuate ladybird (*H. sinuata* Muls.), and the glacial ladybird (*H. glacialis* Fab.). These ladybird beetles do considerable good by destroying the eggs of the overwintered leaf-beetles. Occasionally the ladybirds nearly "wipe out" the eggs which are deposited on certain areas during April and May. A case of this kind was noted during the spring of 1911. On a neglected spot of alkali soil about an acre and a half in extent which had been undisturbed for three years and was covered with a rank growth of "tickle grass" and weeds, the leaf-beetles had hibernated in large numbers. With the advent of warm weather the following spring an abundant supply of Russian thistle, lambs'-quarters, sea purslane, and sea-blite sprang up and the conditions promised to be ideal for the production of an enormous first generation of the beet leaf-beetle. As soon, however, as egg laying began, the ladybirds began their good work, continuing it through April and May and into June, or until the majority of the overwintered beetles had died or scattered to other quarters. Only a very few leaf-beetle larvæ of the first generation developed on this area.

As previously noted, the beet leaf-beetle hibernates on comparatively restricted areas. The ladybirds, however, enjoy a much wider range and hibernate under weeds, grasses, yucca plants, and rubbish wherever convenient shelter is found. Being thus widely scattered, it frequently happens that the ladybirds occur in comparatively small numbers on the areas where the leaf-beetles are ovipositing, and there are always some eggs which escape destruction.

The ladybirds eat the eggs of the beet leaf-beetle practically throughout the season but by far the greater number are destroyed during the spring at a time when aphids and other soft-bodied insects are less plentiful. The ladybirds simply utilize the leaf-beetle eggs as a convenient supply to tide them over from the time of emergence from hibernation until aphids become abundant, which is not strange, as the leaf-beetle eggs have tough shells and are consequently more difficult to eat than aphids.

The ladybirds occasionally destroy newly hatched leaf-beetle larvæ. On the other hand, the ladybird larvæ apparently relish the young larvæ of the leaf-beetles but seldom eat the eggs.

PENTATOMID BUG.

The nymphs and adults of the pentatomid bug *Perillus bioculatus* Fab. var. *claudus* Say feed on the larvæ of the leaf-beetle and the adults also feed on the beetles. The eggs of this bug are of the usual pentatomid type and are deposited in clusters on plants among the eggs of its host. More than one generation is evidently produced annually, although the bugs are rarely abundant enough to reduce the leaf-beetles noticeably. The adult bugs pass through the winter under tufts of grass, frequently among the hibernating leaf-beetles. One generation was under observation at Rocky Ford, Colo. May 1 a female bug was confined in a cage with leaf-beetle larvæ as food. May 7 she deposited a cluster of 17 eggs. The record is as follows:

May 7	Eggs deposited.
May 19	Eggs hatched.
May 25	First molt.
May 30	Second molt.
June 2	Third molt.
June 5	Fourth molt.
June 11	Fifth molt.

The periods of the egg and nymphal stages or instars are as follows:

	Days.
Egg stage	12
First nymph stage	6
Second nymph stage	5
Third nymph stage	3
Fourth nymph stage	3
Fifth nymph stage	6
Total	35

A single species of internal parasite was reared, a tachina fly, *Hypostena* sp.⁵ This fly is rare and few were reared. It seems remarkable that the larvæ of this, as well as of other leaf-beetles, are not more commonly parasitized since they are of good size and feed in exposed positions where they apparently offer an "easy mark" for parasites.

MITE AND SPIDER.

During the latter part of July, 1911, a few large, red larvæ of a mite, *Trombidium* sp. near *muscarum*, were found clinging to the abdomens of a few beetles. They were of rare occurrence and apparently caused the infested beetles no damage.

⁵ Identified by Mr. W. R. Walton.

A large red spider, *Phidippus coloradensis* Thorell, was unintentionally confined with several beetles. This spider seized a beetle and devoured it.

CANNIBALISM.

Occasionally, both in the field and in confinement, nearly full-grown larvæ have been found feeding on the eggs of their own species. This curious habit, however, is not common.

FUNGUS DISEASE.

September 4, 1909, a fungus disease, *Botrytis bassiana* Bals., was found attacking the larvæ at Rocky Ford, Colo. The diseased larvæ were in pupation cells in a small area of moist soil in the corner of a beet field. Twenty per cent of the larvæ in this area were dead and covered with fungus, but very few pupæ were affected. Since this disease was not observed in after years, it is evidently too rare to be of material benefit.

TOADS.

Common toads eat the adult leaf-beetle but have not been found in sufficient numbers on the infested areas to reduce the number of the beetles materially. A medium-sized toad was taken from a badly infested patch of sea-blite and dissected. The stomach contained 39 of the beet leaf-beetle adults, a convergent ladybird (*Hippodamia convergens* Guér.), a grasshopper, and several ants, ground-beetles (Carabidae), and click-beetles (Elateridae).

POULTRY AND WILD BIRDS.

Chickens feed on the beetles readily and under certain conditions may be utilized as a means of controlling this leaf-beetle. This is demonstrated by the following experiment: On one occasion a flock of chickens was turned into a badly infested field of beets at Rocky Ford. That evening a chicken was killed and 431 beetles and a few larvæ were taken from the crop. The chickens were allowed to remain among the beets and two weeks later another bird was killed. The crop contained 250 beetles.

The Bureau of Biological Survey has found specimens of the beet leaf-beetle in the stomachs of the starling (*Sturnus vulgaris*) and prairie chicken (*Tympanuchus americanus*) and of other species of the genus *Monoxia* in the stomachs of the northern and Wilson's phalaropes (*Lobipes lobatus* and *Steganopus tricolor*), least flycatcher (*Empidonax minimus*), English and vesper sparrows (*Passer domesticus* and *Poæcetes gramineus*), violet-green swallow (*Tachycineta thalassina*), and pipit (*Anthus rubescens*).

January 23, 1912, a flicker (*Colaptes auratus*) was observed scratching in a tuft of grass under which a number of beetles were in hibernation, but there was no positive evidence that the bird ate any of the beetles.

Flocks of blackbirds frequently congregate in fields of beets which are strongly infested by the beet leaf-beetles. August 17, two such birds were shot, but their crops were found to contain nothing except vegetable matter. No noticeable reduction in the number of the beetles could be observed during times when blackbirds frequented the fields, and it may be concluded that they do not normally feed on these insects.

OTHER CHECKS.

Occasionally cattle or horses are turned on to areas where the beetles are in hibernation, and a few beetles may be trampled upon and killed, but as a rule few are destroyed in this way.

Ordinarily this insect is not greatly affected by climatic conditions. Remarkably few hibernating beetles die during the winter. During January of one year a low spot upon which many beetles were in hibernation was flooded to a depth of 3 or 4 inches by melting snow. The majority of the beetles saved themselves by climbing up the grass stems above the water. On this area there were a few tufts of grass which were covered with a crust of snow, and here the beetles were trapped under the crust, and were drowned; but this case of winter killing is exceptional, and usually the beetles are uninjured by rain, snow, or cold.

Some of the eggs which are deposited early in the spring, when the nights are still frosty, become cracked and fail to hatch. Possibly this is caused by the cold, as no cracked eggs have been found during warm weather. In early spring young larvæ are occasionally knocked from their food plants, and killed by the cold dashing rains, but the number destroyed in this way is usually very small.

EXPERIMENTS WITH INSECTICIDES.

The following insecticides were tested against the beet leaf-beetle at Rocky Ford, Colo.:

Spraying experiments.

- No. 1. Paris green, 1 pound to 50 gallons of water.
- No. 2. Paris green, 1 pound, and whale-oil soap, 3 pounds, to 50 gallons.
- No. 3. Paris green, 1 pound, and rosin-fish-oil soap, 3 pounds, to 50 gallons.
- No. 4. Paris green, 1 pound, and laundry soap, 2 pounds, to 50 gallons.
- No. 5. Paris green, 1 pound, and lime, 1 pound, to 50 gallons.
- No. 6. Paris green, 1½ pounds to 50 gallons.
- No. 7. Paris green, 1½ pounds, and whale-oil soap, 3 pounds, to 50 gallons.
- No. 8. Paris green, 1½ pounds, and whale-oil soap, 3 pounds, to 50 gallons.

- No. 9. Paris green, 2 pounds, and whale-oil soap, 3 pounds, to 50 gallons.
- No. 10. Arsenate of lead, 3 pounds, and laundry soap, 3 pounds, to 50 gallons.
- No. 11. Arsenate of lead, 3 pounds, and Paris green, $\frac{1}{2}$ pound, to 50 gallons.
- No. 12. Arsenate of lead, 5 pounds to 50 gallons.
- No. 13. Arsenate of lead, 5 pounds, and Paris green, 1 pound, to 50 gallons.
- No. 14. Arsenate of lead, 5 pounds, and lime-sulphur solution, 2 gallons, to 50 gallons.
- No. 15. Zinc arsenite, $2\frac{1}{2}$ pounds, and Paris green, $\frac{1}{2}$ pound, to 50 gallons.
- No. 16. Zinc arsenite, 2 pounds, and whale-oil soap, 3 pounds, to 50 gallons.
- No. 17. Zinc arsenite, $2\frac{1}{2}$ pounds, and whale-oil soap, $2\frac{1}{2}$ pounds, to 50 gallons.

Dusting experiments.

- No. 18. Paris green, 1 pound to 50 pounds of flour.
- No. 19. Paris green, 2 pounds to 50 pounds of flour.
- No. 20. Paris green, 5 pounds to 50 pounds of flour.
- No. 21. Paris green, 1 pound to 50 pounds of wood ashes.
- No. 22. Paris green, 2 pounds to 50 pounds of wood ashes.

Several additional experiments were made, especially with lead chromate at rates varying from about $\frac{1}{2}$ pound to 3 pounds in 50 gallons of water, but this substance proved to be utterly worthless either as a stomach poison or as a repellent against this insect. The same is true in its application against most other forms of insect pests.

In the course of these experiments more than 60 acres of sugar beets were sprayed or dusted. With the spraying experiments preliminary tests were made with knapsack sprayers, and the poisons which gave promise of being successful were later tried out on a larger scale with field sprayers. The "dust" was applied with a "powder gun" or was shaken upon the foliage from cheesecloth sacks.

Without exception the poisons tested in the foregoing experiments proved unsatisfactory against the adults but in most cases were partially or wholly effective against the larvæ. The failure to control the beetles was due to the fact that, as a rule, they refused to eat the poisoned foliage except when no other food was available. All the poisons, except lead chromate, killed the beetles whenever eaten. Usually, however, the beetles promptly deserted the treated plants but returned after the poison was washed away or blown from the foliage or after new leaves developed. The poisons were usually effective as repellents for periods of from 2 to 5 days.

The poisons with which whale-oil soap or lime-sulphur solution were used served as repellents for longer periods than when applied

alone. The benefits derived from the repellent effect were, however, usually of little importance.

Paris green, whenever eaten by the beetles, proved somewhat quicker in its killing effect than either arsenate of lead or zinc arsenite. Paris green, 1 pound to 50 gallons of water, gave more promising results than any other mixture. When applied thoroughly to the upper and lower surfaces of the leaves a fairly good number of beetles were killed but when applied to the upper surface the results were entirely unsatisfactory. In one experiment at the foregoing strength a large number of beetles, which had recently emerged from their cells and were too soft to fly, crawled to the sprayed beets and were promptly killed. Such instances as this, however, are exceptional. As a rule the newly-developed beetles feed upon weeds until they become hardened and then fly to the beets. When they are able to fly the majority almost invariably desert or avoid sprayed or dusted plants. Even in exceptional cases when the beetles are killed, others usually take their places promptly, and unless frequent applications of the poison are made the results are of little benefit. In one experiment 20 acres of beets were sprayed twice and in another 5 acres were sprayed three times, but the results were only temporary and did not justify the expense.

In dusting experiments the majority of the beetles refused to eat the treated foliage and few were killed. The "dust" served as a repellent for a few days but this protection was too brief to be of practical benefit.

The larvæ are readily killed with Paris green but they seldom occur in sufficient number on sugar beets to make it profitable to spray for them alone. The weeds, upon which the bulk of the larvæ normally develop, are usually scattered about in inaccessible places and it is somewhat doubtful if they could be profitably sprayed, except in cases of severe outbreaks of this insect.

RECOMMENDATIONS FOR CONTROL.

Basing an opinion on the experiments and observations which were conducted in the Arkansas Valley of Colorado during four seasons, it may be concluded that arsenicals can not be entirely depended upon as a practical means of controlling the beet leaf-beetle.

As previously mentioned, the majority of the beetles congregate, during the fall, on or about alkali areas. Here they hibernate on the surface of the ground, under tufts of grass, heaps of weeds, or other shelter. The most effective and practical method of control is, therefore, to destroy the beetles in their hibernating quarters. This may be accomplished easily and cheaply between the middle of November and the first of March, by burning the dead grass and weeds.

The beetles may be trapped by placing heaps of weeds, or bundles of straw or hay, on or near the alkali areas. It is advisable to place such "traps" not later than August, so that they may become well settled before the beetles seek them for winter quarters. After the beetles have gone into hibernation under the "traps" they may be destroyed by burning.

The effectiveness of burning depends upon the thoroughness with which the beetles and their hibernating quarters are destroyed. Careless, slipshod work will invariably fail to produce the desired results.

Occasionally an infested field is so situated that a flock of chickens may be quartered in it. Chickens relish the beetles, and may be depended upon to do good work in reducing infestation.

The almost invariable failures which have followed the efforts to control the beet leaf-beetle with insecticides have had a tendency to discourage the beet growers, and many regard the injuries inflicted by this pest with indifference or as an unavoidable evil.

The results of the investigations which are here reported will serve to clear up many hitherto unpublished facts regarding this insect. Among others the practically complete knowledge of the insect's life history shows that this pest can be controlled by simple and inexpensive means. The destruction of the beetles by burning them in their hibernating quarters has proved so thoroughly effective and so easily accomplished that there is little or no excuse for beet growers to continue to submit to injury from this insect in the future.

SUMMARY.

In the Rocky Mountain States sugar beets and garden or table beets, Swiss chard, and spinach are subject to attack by the beet leaf-beetle (*Monoxia puncticollis* Say), or "alkali bug," an insect resembling the elm leaf-beetle.

This insect normally lives in alkali regions, breeding on such weeds as the sea-blites, Russian thistle, salt-bush, and lamb's-quarters, but when it becomes abundant there is an overflow to cultivated plants, which are attacked and often greatly injured.

Injury is accomplished chiefly by the larvæ, although the beetles also do much damage, not infrequently eating young beets "down to the ground." Many hundreds of acres of beets are destroyed every year. The beetles also act as carriers of a fungus disease.

The beetles issue from their winter quarters during March and April, feed on weeds, mate, and within a short time begin laying their eggs. The rounded oval, orange-yellow eggs are laid on the underside of the leaves in masses of varying number, from 2 or 3 to 50, a single female depositing between 300 and 400 eggs and even

more. These hatch in from 8 to 18 days, depending upon the temperature, and the larvæ complete their growth in from 14 to 29 days.

The larvæ feed in exposed positions on either the upper or lower surface of the leaves, eating holes in them, frequently cutting entirely through the leaf. When mature, the larvæ leave the plants and burrow into the earth to a depth of from half an inch to 2 inches and form cells in which the soft yellow pupæ develop. The pupal period requires 8 or 9 days, and then the beetles emerge.

Two generations and a partial third generation are produced annually in the Arkansas Valley of Colorado, where the species has been studied.

Hibernation is passed as a beetle in alkali areas under tufts of grass, heaps of dead weeds, and other rubbish, and the grower may take advantage of the knowledge of this habit to destroy the beetles in their winter quarters, which has proved an effective and practicable method of control.

The best time for this work is between the middle of November and the first of March, when the dead grass and weeds may be burned. The effectiveness of this method depends on the thoroughness with which the hibernating quarters of the beetles are destroyed.

The use of arsenicals has not been entirely satisfactory in the control of this pest.

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Contribution from the Bureau of Chemistry, CARL L. ALSBERG, Chief, and the Bureau of Entomology, L. O. HOWARD, Chief.



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EXPERIMENTS ON THE TOXIC ACTION OF CERTAIN GASES ON INSECTS, SEEDS, AND FUNGI.

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INTRODUCTION.

Experiments made at American University by the Bureau of Entomology of the United States Department of Agriculture, in cooperation with the Chemical Warfare Service of the United States War Department, on the action of certain toxic gases upon the body louse (*Pediculus corporis* De G.) indicated that further investigation with other insects might be profitable, especially since very little work had been done with respect to their action on insects,¹ fungi, and seeds. Accordingly a committee² was appointed to plan a series of experiments to determine the value of these gases for fumigating purposes.

The gases of war value and the apparatus used at American University were obtained through the courtesy of the Chemical Warfare Service. The collection and rearing of the insects and observa-

¹ Bertrand, Brocq-Rousseau and Dassonville (Compt. rend., 169 (1919): 441, 880, 1059, 1061, 1428) have conducted some experiments with chloropicrin on bedbugs and charancon (weevils); Moore (J. Econ. Entomol., 11 (1918): 357) has done some work with chloropicrin against bean weevil (*Bruchus obtectus* Say.), Angoumois grain moth (*Sitotroga cerealella* Oliv.), Indian meal moth (*Plodia interpunctella* Hbn.), Mediterranean flour moth (*Ephesia kuehniella* Zell.), and confused flour beetle (*Tribolium confusum* Duval), as well as (J. Lab. Clin. Med., 3 (1918): 267) for fumigating clothing for the destruction of the clothes louse (*Pediculus corporis* [vestimentil]). Moore and Graham (J. Agr. Research, 12, No. 9 (1918): 579) tested the action of chloropicrin on potato beetle eggs (*Leptinotarsa decemlineata* Say.).

² This committee consisted of R. H. Hutchison and E. A. Back, of the Bureau of Entomology, E. R. Sessler, of the Federal Horticultural Board, and I. E. Neifert, of the Bureau of Chemistry.

tions upon them were performed by G. L. Garrison. The germination tests were made by W. L. Goss, of the Seed-Testing Laboratory of the Bureau of Plant Industry, and the fungicidal results were determined by J. Monteith, jr., and H. F. Bain, of the Federal Horticultural Board, and C. C. Thomas, of the Bureau of Plant Industry.

EXPERIMENTAL WORK.

GENERAL PROCEDURE.

Nearly 800 fumigations, in which 20,000 insects of about 15 different species were fumigated, were made. The following were fumigated in small glass cylinders, both ends of which were covered by cloth held in place by rubber bands: Ants (*Tetramorium caespitum* Fab., *Monomorium minimum* Buckley, *Monomorium pharaonis* L., *Lasius niger* L., var. *americanus* Emery); bedbugs (*Cimex lectularius* L.); bedbug eggs; potato beetles (*Leptinotarsa decemlineata* Say and *Epitrix cucumeris* Harris); flat grain beetles (*Laemophloeus minutus* Oliv.); sawtooth grain beetles (*Silvanus surinamensis* L.); grain borers (*Rhizopertha dominica* Fab.); flies (*Phormia regina* Meig., *Calliphora vomitoria* L., *Musca domestica* L., *Stomoxys calcitrans* L., *Chrysomya macellaria* Fab., and *Lucilia sericata* Meig.); roaches (*Blattella germanica* L.); roach egg pods; flour weevils (*Tribolium ferrugineum* Fab.); and rice weevils (*Calandra oryzae* L.). The following insects were fumigated on their hosts: Aphids (*Myzus persicae* Sulz.); white fly (*Aleyrodes vaporariorum* Westw.); Phyllostachys bamboo mite (*Tarsonemus* sp.); and red spider (*Tetranychus bimaculatus* Harvey).

Checks were kept on all insects, and no results are given for insects whose check showed any dead. The observations were begun when the insects were removed from the fumigatorium, and continued up to the time the percentage of dead became constant for any two successive days. The checks and treated insects were kept under the same conditions until the final observation was made. All of the insects, except ants, aphids, red spiders, and white flies, were held in the container in which they were fumigated. The bedbug eggs were fumigated and kept in chiffon-covered pill boxes, in which the eggs had been deposited. After fumigation the ants were removed to tumblers containing moist sand. Having been fumigated on their hosts, aphids, red spiders, and white flies were transferred to glass tumblers containing moist sand and fresh uninfested material. Roach egg pods were handled in the same manner as ants.

The following fungi were treated: *Fusarium*, *Ascochyta*, *Penicillium*, *Colletotrichum*, and *Sclerotium*. In some cases these fungi were placed on a petri dish in a drop; in others, sterilized seeds were inoculated by a spore suspension, and exposed in the same manner as the insects.

The apparatus used to maintain concentration and humidity consisted of a gas flow meter and a gas-air flow meter, both calibrated so that the exact amount of gas and gas air flowing at any one time was known, and could be maintained throughout the experiment. The flow of gas-air mixture was kept at approximately normal atmospheric pressure by having the inflowing air withdrawn as fast as it entered. The blast and suction were kept constant by pressure and suction regulators in the form of heads of water through which the excess air was allowed to bubble. The gases of fairly high vapor pressure (those whose pressure was sufficiently great to force them through the gas flow meter) were kept in small steel cylinders.

In order to follow the air through the apparatus and to make more clear the production of a given concentration of a definite humidity, it will be necessary to trace the air from the blast cock through the apparatus. First, the air was passed over the pressure regulator, then into three bottles of sulphuric acid solution having a density which would produce the humidity desired. From there it was forced through glass wool to take up any acid spray; thence to the mixing chamber, where it was joined by the gas. The mixture passed through a calibrated flow meter and into the fumigation jar, which was connected with the suction line that drew off the air and caused the concentration to rise to the desired strength of gas air; that is, the suction line took care of all of the excess gas air.

The valve on the gas cylinder being open, the gas pressure was kept constant by a head of liquid, and the gas was forced through a calibrated flow meter into the mixing chamber. As the humidity of the blast varied from day to day, an arbitrary humidity (40 per cent relative, which is common in Washington) was adopted.

In most of the experiments a 5-liter jar constituted the fumigation chamber. Inasmuch as the rate of flow of gas air was about two liters per minute, and the minimum exposure was seven minutes, ample time was allowed for the change from air to gas air of the proper concentration.

In the case of chloropicrin (which has a low vapor pressure), it was necessary to draw the air through the fumigant for the high concentration. For lower concentrations only part of the air was drawn through and the rest by-passed, and then both reunited as they entered the line to the gas-air flow meters.

The exact concentration of gas was usually determined by absorption in alkaline solution. The details for the concentration determination for each gas are given under the heading of that gas.

The following gases were investigated: Phosgene, cyanogen chlorid, arsine, chloropicrin, illuminating gas, carbon monoxid, and hydrocyanic acid. The last, which is a standard fumigant against many insects, was used for comparison.

PHOSGENE.

Phosgene, or carbonyl chlorid (COCl_2), molecular weight 98.92, has a liquid density, at 20°C . under its own pressure, of 1.38. Its boiling point is 8.2°C . The vapor pressure at 20°C . is 1,216 mm. of mercury. It is corrosive to metals and a decolorizer. It is extremely toxic to human beings, and is rather difficult to handle and control.

The concentration of the gas-air mixture was determined by allowing the gas air to pass into a solution of 5 per cent alcoholic sodium hydroxid solution for one minute, then neutralizing with acetic acid and titrating with N/10 silver nitrate. Concentrations of from 0.5 to 4 per cent and exposures for from seven minutes to two hours were tried. The minimum lethal dose of phosgene, with the minimum time to kill, as compared with that of hydrocyanic acid, is given in Table 1.

TABLE 1.—Relative insecticidal action of phosgene and hydrocyanic acid.

Insects.	Phosgene (100 per cent lethal).				Hydrocyanic acid (100 per cent lethal).			
	Con- centra- tion.	Time of ex- posure.	Tem- pera- ture.	Rela- tive hu- midity.	Con- centra- tion.	Time of ex- posure.	Tem- pera- ture.	Rela- tive hu- midity.
Ants (<i>Monomorium minimum</i> Buck- ley, <i>Lasius niger</i> L., var. <i>ameri- cinus</i> Emery)	0.5	30	19	19				
Ants (<i>Tetramorium caespitum</i> Fab.)					0.2	30	25	40
Aphids (<i>Myzus persicae</i> Sulz.)	1.0	30	31	40	.2	60	24	40
Beet bugs (<i>Cimex lectularius</i> L.)	2.0	120	26	40	2.0	30	27	40
Bedbug (<i>Cimex lectularius</i> L.) eggs	2.0	120	24	40				
Beetles, Colorado potato (<i>Leptino- tarsa decemlineata</i> Say)	4.0	120	30	40	.5	15	30	40
Beetle, Colorado potato (<i>Leptinotarsa decemlineata</i> Say) larvae	4.0	120	30	40	.5	15	30	40
Beetles, Flat grain (<i>Lacmophlaeus minutus</i> Oliv.)	1.0	120	29	40	1.0	60	26	40
Beetles, Potato-tolla (<i>Epitrix cucumeris Harris</i>)	1.0	60	30	40	.5	7	27	40
Beetles, Sawtooth grain (<i>Silvanus surinamensis</i> L.)	1.0	120	28	40	1.0	30	28	40
Borers, Grain (<i>Rhizopertha dominica Fab.</i>)	2.0	60	29	40	1.0	30	30	40
Flies ¹	2.5	7	26	40	3.1	37	25	40
Fly larvae ¹	3.0	120	26	40	.1	30	25	40
Fly, White (<i>Ategyodes vaporariorum Westw.</i>)	1.0	30	22	40	3.1	37	30	40
Lice, Body (<i>Pediculus corporis</i> Deg.) eggs	3.0	120	23	40				
Mite, Phyllostachys bamboo (<i>Tar- sonemus</i> sp.)	1.5	30	25	40	.2	60	24	40
Roaches (<i>Blattella germanica</i> L.)	1.5	120	27	40	.2	15	25	40
Roach (<i>Blattella germanica</i> L.) egg pods	3.0	120	30	40				
Spiders, Red (<i>Tetranychus bimacu- latus</i> Harvey)	.5	60	31	40	.2	30	23	40
Weevils, Flour (<i>Tribolium ferrugi- neum</i> Fab.)	7 4.0	120	23	40	1.0	30	34	40
Weevils, Rice (<i>Calandra oryzae</i> L.)	4.0	120	26	40	4.0	120	28	40

¹ *Musca domestica* L.; *Calliphora vomitoria* L.; *Muscina stabulans* Fall.² Equal to or less than but not more than.⁵ 90 per cent killed.³ Not minimum lethal treatment.⁶ 90.6 per cent killed.⁴ *Muscina stabulans* Fall.⁷ 86 per cent killed.

The results in Table 1 show that in every case phosgene is less effective as an insecticide than hydrocyanic acid.

Several varieties of seeds were fumigated with phosgene in the higher concentrations, the results of which are shown in Table 2.

TABLE 2.—*Effect of phosgene on seed germination.*

Kind of seed.	Germination.			
	Check.	Exposed for 30 minutes (temp., 27° C.; relative humidity, 40).		Exposed for 120 minutes (temp., 27° C.; relative humidity, 40).
		2 per cent concentration.	3 per cent concentration.	3 per cent concentration.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Alfalfa, Dakota.....	81.5	78.5	72.0	82.0
Carrot, Danvers half long.....	82.5	71.0	69.5	75.0
Clover, Crimson.....	44.0	42.0	30.5	46.5
Grass, Orchard.....	42.5	49.0	38.5	46.5
Lettuce, Salamander.....	86.5	79.0	66.5	70.5
Millet, Turkestan.....	59.5	61.5	45.5	19.0
Muskmelon, Rocky Ford.....	63.5	51.0	3.5	0.0
Onion, Australian brown.....	52.0	54.5	33.0	51.5
Radish, White icicle.....	95.0	91.5	90.0	93.0
Wheat, Bluestem.....	48.5	48.0	40.0	20.0

Muskmelon, millet, and wheat were injured the most. The other seeds were not materially affected. In a few cases there seemed to be some stimulation.

Phosgene proved useless as a fungicide against *Fusarium*, *Ascochyta*, *Penicillium*, and *Colletotrichum*.

Inasmuch as phosgene has no advantage over the fumigants now in use and is less efficient, it is not recommended.

ARSINE.

Arsine, or arseniuretted hydrogen (AsH_3), molecular weight 77.98, has a liquid density, under its own pressure, of 1.36 at 20° C. Its boiling point is -55° C. The vapor pressure is 8,780 mm. of mercury at 10° C.

Arsine is toxic to human beings, and extremely harmful to live plants, in which it produces chlorotic conditions. Metals and glass when in contact with the gas become coated with a fine, mirrorlike deposit of arsenic.

The gas was generated by dropping water on magnesium arsenid and collecting the arsine over saturated sodium chlorid solution. The concentration was determined by absorbing the gas in N/100 iodine solution and titrating with N/100 sodium thiosulphate solution.

Concentrations of from 0.5 to 3 per cent, and exposures of from seven minutes to two hours were used. The minimum lethal dose of arsine for certain periods of time, as compared with that of hydrocyanic acid, is given in Table 3.

TABLE 3.—Relative insecticidal action of arsine and hydrocyanic acid.

Insects.	Arsine (100 per cent lethal).				Hydrocyanic acid (100 per cent lethal).			
	Con- centra- tion.	Time of ex- posure.	Tem- pera- ture.	Rela- tive hu- midity.	Con- centra- tion.	Time of ex- posure.	Tem- pera- ture.	Rela- tive hu- midity.
Ants (<i>Lasius niger</i> L., var. <i>americanus</i> Emery).....	P. ct. 2.0	Min. 60	° C. 20	40	P. ct. 1 0.2	Min. 30	° C. 25	40
Aphids (<i>Myzus persicae</i> Sulz.).....	1.0	60	25	40	.2	60	24	40
Bedbugs (<i>Cimex lectularius</i> L.).....					2.0	30	27	40
Beetles, Colorado potato (<i>Leptinotarsa decemlineata</i> Say).....					.5	15	30	40
Beetles, Flatgrain (<i>Laemophlaeus minutus</i> Oliv.).....	.5	60	24	40	1.0	60	26	40
Beetles, Potato flea (<i>Epitrix cucumeris</i> Harris).....	1.0	60	20	40	.5	7	27	40
Beetles, Sawtooth grain (<i>Silvanus surinamensis</i> L.).....	.5	60	25	40	1.0	30	28	40
Borers, Grain (<i>Rhizopertha dominica</i> Fab.).....	.5	15	25	40	1.0	30	30	40
Flies ²	.5	60	21	40	³ .1	7	20	40
Fly larvae ⁴	1.0	30	25	40	.1	30	25	40
Fly, White (<i>Aleyrodes vaporariorum</i> Westw.).....	.5	30	20	40	³ .1	7	30	40
Mite, Phyllostachys bamboo (<i>Tarsonemus</i> sp.).....	2.0	60	29	40	.2	60	24	40
Roaches (<i>Blattella germanica</i> L.).....	1.0	60	25	40	.2	15	25	40
Roach (<i>Blattella germanica</i> L.) egg pods.....	3.0	60	25	40				
Spiders, Red (<i>Tetranychus bimaculatus</i> Harvey).....	⁵ 3.0	120	29	40	.2	30	23	40
Weevils, Flour (<i>Tribolium ferrugineum</i> Fab.).....	1.0	60	22	40	1.0	30	34	40
Weevils, Rice (<i>Calandra oryzae</i> L.).....	.5	60	29	40	4.0	120	28	40

¹ *Lasius niger* L., var. *americanus* Emery and *Tetramorium caespitum* Fab.² *Musca domestica* L.; *Stomoxys calcitrans* L.; *Chrysomya macellaria* Fab.; *Lucilia sericata* Meig.; *Phormia regina* Meig.³ Not minimum lethal treatment.⁴ *Muscina stabulans* Fall.⁵ 99 per cent killed.

In most cases, longer exposure and higher concentrations were necessary in using arsine than in using hydrocyanic acid, two notable exceptions being grain borers and rice weevils. Arsine has many disadvantages as a fumigant, and can not be recommended for this purpose.

TABLE 4.—Effect of arsine on seed germination.

Kind of seed.	Germination.		
	Check.	2 per cent concentration (temp., 22° C.; relative humidity, 40).	3 per cent concentration (temp., 22° C.; relative humidity, 40).
	Per cent.	Per cent.	Per cent.
Alfalfa, Dakota.....	79.5	81.0	76.0
Barley, Winter.....	82.5	80.5	85.5
Carrot, Oxheart.....	89.5	76.5	77.5
Corn, Miner's yellow dent.....	83.5	91.5	88.0
Field pea, Kaiser.....	91.5	82.5	84.0
Flax, Oregon.....	88.5	88.5	86.5
Lettuce, Black-seeded tennis ball.....	76.0	82.0	78.5
Muskmelon, Burnell's gem.....	79.0	76.0	78.0
Onion, Australian brown.....	24.5	23.5	31.0
Radish, Icicle.....	90.5	97.0	96.5
Rape, Winter.....	48.5	50.5	40.5
Rice, Mataribune.....	44.0	54.0	44.0
Soy bean, Mammoth yellow.....	18.0	24.5	4.5
Timothy.....	74.5	72.5	83.5
Wheat, Crimean.....	85.5	88.0	87.5

In some instances germination seems to have been stimulated, but for the most part the gas had no appreciable effect on the seeds.

Inasmuch as the check on soy beans was poor, the results in this case may be ignored.

Arsine does not prevent the growth of *Fusarium*, *Ascochyta*, or *Colletotrichum* exposed to it in concentrations up to and including 3 per cent for 60 minutes. It is of no value as a fungicide.

CYANOGEN CHLORID.

Cyanogen chlorid (CNCl), molecular weight 61.47, has a liquid density of 1.186 at 20° C. under its own pressure. Its boiling point is 15° C. The vapor pressure at 20° C. is 1,002 mm. of mercury. It is colorless, has an odor somewhat similar to that of hydrocyanic acid, and produces a violent lachrymosal effect. One volume of water dissolves 25 volumes of the gas. Cyanogen chlorid is less dangerous to human beings than hydrocyanic acid, because it can be detected when present in very low concentrations, while its presence in higher concentrations is unbearable because of its lachrymosal effect. Plant life is injuriously affected by cyanogen chlorid.

The concentration was determined in the same manner as was that of phosgene. Concentrations of from 0.1 to 4 per cent and exposures of from seven minutes to two hours were tried on insects. Fungi and seeds were exposed for longer periods.

The minimum lethal dose of cyanogen chlorid, as compared with that of hydrocyanic acid, is given in Table 5.

TABLE 5.—Relative insecticidal action of cyanogen chlorid and hydrocyanic acid.

Insects.	Cyanogen chlorid (100 per cent lethal).				Hydrocyanic acid (100 per cent lethal).			
	Con- centra- tion.	Time of ex- posure.	Tem- pera- ture.	Rela- tive hu- midity.	Con- centra- tion.	Time of ex- posure.	Tem- pera- ture.	Rela- tive hu- midity.
	<i>P. ct.</i>	<i>Min.</i>	<i>° C.</i>		<i>P. ct.</i>	<i>Min.</i>	<i>° C.</i>	
Ants (<i>Monomorium pharaonis</i> L.)....	0.2	30	26	40	¹ 0.2	30	25	40
Aphids (<i>Myzus persicae</i> Sulz.).....	.1	30	26	40	.2	60	24	40
Bedbugs (<i>Cimex lectularius</i> L.).....	1.0	30	27	40	2.0	30	27	40
Bedbug (<i>Cimex lectularius</i> L.) eggs...	1.0	60	28	40				
Beetle, Colorado potato (<i>Leptino- tarsa decemlineata</i> Say.).....	.5	30	28	40	.5	15	30	40
Beetle, Colorado potato (<i>Leptinotarsa decemlineata</i> Say.) larvae.....	.5	15	30	40	.5	15	30	40
Beetles, Flat grain (<i>Laemophilaeus minutus</i> Oliv.).....	.5	120	31	40	1.0	60	26	40
Beetles, Potato flea (<i>Epitrix cucumeris Harris</i>).....	.5	15	27	40	.5	7	27	40
Beetles, Sawtooth grain (<i>Silvanus sur- inamensis</i> L.).....	1.0	60	27	40	1.0	30	28	40
Borers, Grain (<i>Rhizopertha dominica Fab.</i>).....	1.0	60	23	40	1.0	30	30	40
Flies ²	.1	15	25	40	³ .1	7	25	40
Fly larvae.....	.5	15	24	40	.1	30	25	40
Fly, White (<i>Aleyrodes vaporariorum Westw.</i>).....	.2	7	29	40	³ .1	7	30	40
Mite, Phyllostachys bamboo (<i>Tarson- emus</i> sp.).....	.2	30	29	40	.2	60	24	40
Roaches (<i>Blattella germanica</i> L.).....	.5	30	25	40	.2	15	25	40
Roach (<i>Blattella germanica</i> L.) egg pods.....	2.0	60	23	40				
Spiders, Red (<i>Tetranychus bimaculatus Harvey</i>).....	.5	15	28	40	.2	30	23	40
Weevils, Flour (<i>Tribolium ferrugine- um</i> Fab.).....	2.0	60	24	40	1.0	30	34	40
Weevils, Rice (<i>Calandra oryzae</i> L.)....	⁴ 4.0	120	27	40	4.0	120	28	40

¹ *Tetramorium caespitum* Fab., and *Lasius niger* L., var. *americanus* Emery.

² *Musca domestica* L.

³ Not minimum lethal treatment.

⁴ 96 per cent killed.

The results in Table 5 show that the action of cyanogen chlorid as an insecticide is practically the same as that of hydrocyanic acid.

A preliminary series of germination tests run on several varieties of seeds showed that for the most part but little injury was done the seeds which were exposed to cyanogen chlorid for six hours at 1 per cent concentration, or for two hours at 3 per cent concentration. Exposure for more than six hours, however, affected injuriously the germination quality. Consequently, a longer series, with exposures not exceeding six hours, was run. The results thus obtained are reported in Table 6.

TABLE 6.—*Effect of cyanogen chlorid on seed germination.*

Kind of seed.	Germination.				
	Check.	1 per cent concentration.		3 per cent concentration, 1 hour	1 per cent concentration, 1 hour
		3 hours (temp., 23° C.; relative humidity, 40; atmospheric pressure, normal).	6 hours (temp., 23° C.; relative humidity, 40; atmospheric pressure, normal).	(temp., 23° C.; relative humidity, 40; atmospheric pressure, normal).	(temp., 23° C.; relative humidity, 22; atmospheric pressure, vacuum).
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Barley, Himalaya.....	75.5	24.5	27.0	26.0	23.5
Barley, Kentucky winter.....	97.5	83.5	77.5	85.5	86.5
Barley, Manchuria.....	99.0	81.0	76.0	82.5	90.0
Barley, Moriart.....	99.5	92.0	91.5	96.0	97.0
Carrot, Danvers half long.....	77.5	78.5	72.5	75.0	74.5
Chenopodium ambrosoides.....	82.25	84.25	82.5	83.75	63.5
Clover, Alsikl.....	84.0	86.75	86.5	86.5	87.5
Clover, White.....	94.0	92.75	92.0	92.25	92.25
Clover, White sweet.....	83.5	82.5	77.5	80.5	73.5
Cucumber, Boston pickle.....	88.0	89.5	91.5	93.5	93.5
Flax, Salem, Oreg.....	85.5	86.5	85.0	85.5	86.0
Grass, Bermuda.....	92.5	88.0	84.5	88.0	85.0
Grass, Crested dog's tail.....	13.0	1.5	1.5	1.5	.5
Grass, Red top.....	86.0	80.0	89.75	85.0	85.5
Grass, Timothy.....	77.25	70.0	74.25	78.5	68.5
Kaoliang, Brown.....	96.0	21.5	20.5	27.0	25.0
Lettuce, Black-seeded Simpson.....	81.5	83.0	73.0	80.0	68.5
Lettuce, Grand Rapids.....	96.0	94.5	97.5	96.0	90.5
Lettuce, Salamander.....	67.5	72.0	78.5	73.5	72.0
Millet, Kursk.....	52.5	43.0	3.0	29.5	29.0
Milo, Dwarf.....	78.5	35.5	29.5	37.5	34.5
Muskmelon, Rocky Ford.....	76.0	66.0	76.5	75.5	71.0
Oats, Naked.....	91.0	69.0	59.5	67.0	61.5
Oats, Nebraska No. 21.....	95.5	78.0	86.0	86.5	90.5
Oats, Oregon winter turf.....	99.0	82.5	90.5	84.5	82.5
Oats, Swedish select.....	97.5	74.5	64.5	78.5	81.0
Parsley, Champion moss curled.....	81.5	79.5	78.0	81.0	77.5
Radish, Early scarlet turnip.....	97.5	92.5	92.0	95.5	96.5
Radish, Long scarlet short top.....	98.5	97.5	96.5	97.0	97.5
Radish, White icicle.....	90.5	84.0	85.5	87.5	90.0
Rice (grown in California).....	94.0	90.0	89.5	92.5	85.0
Rice (grown in Louisiana).....	94.5	97.0	92.5	97.0	83.5
Rice (grown in Porto Rico).....	83.0	81.0	75.0	87.5	58.0
Salvia hispanica.....	36.5	21.5	20.5	18.5	16.5
Soy bean, Biloxi.....	90.0	59.0	88.0	89.0	95.0
Soy bean, Haberlandt.....	97.0	73.0	94.0	64.0	97.0
Teff.....	63.5	54.5	56.0	62.75	52.25
Trefoil, Yellow.....	38.5	31.5	33.0	26.0	33.5
Velvet bean, Alabama.....	96.0	81.0	85.0	65.0	89.0
Vetch, Hairy.....	85.5	84.5	92.5	84.0	86.5
Vicia villosa.....	97.5	99.5	99.0	98.5	96.0
Wheat, Arontka.....	90.5	83.5	73.0	84.0	82.0
Wheat, Kharkoo.....	91.5	51.0	42.5	59.5	58.0
Wheat, Marquis.....	92.5	53.0	41.5	40.5	40.0
Wheat, White Australian.....	95.5	55.5	46.0	63.0	57.0

The germination of wheat, oats, and barley is lowered noticeably by treatment with cyanogen chlorid, and that of *Salvia hispanica*, kaoliang, velvet bean, milo, millet, and grass is injuriously affected.

Based on its action on *Ascochyta*, *Colletotrichum*, *Fusarium*, *Penicillium*, and *Sclerotium*, cyanogen chlorid shows possibilities of being an effective fungicide at a concentration of approximately 3 per cent, after an exposure of about 2 hours. The results of numerous experiments with fungi and bacteria on seeds indicate that this gas may be used against such organisms. Further work, however, is necessary to definitely determine this.

It having been shown that cyanogen chlorid is as poisonous to insects as hydrocyanic acid and also that it might prove useful as a fungicide for the treatment of stored products, some experiments were conducted to determine its effect on metals, paint, varnish and fabrics.

No effect was visible on the following metals, which, after having been cleaned and polished, were exposed to 1 per cent cyanogen chlorid for 24 hours in a fumigation box:

Aluminum.	Iron.
Brass.	Steel.
Copper.	Tin.
Galvanized iron.	Zinc.

Several paints and varnishes were exposed to a 1 per cent concentration of cyanogen chlorid for 24 hours in a fumigation box. In making these tests, a double coat of the paint or varnish was put on a 2-inch strip of pine and allowed to dry thoroughly. The treated strips were then fumigated, after which they were examined microscopically for change in finish, and also their color was compared with that of the corresponding unfumigated coating. No effect was visible in the case of the following:

American blue.	Lampblack.
American vermilion.	Lead and oil.
Burnt sienna.	Raw sienna.
Burnt umber.	Red lead.
Chrome green, medium.	Rose pink.
Chrome yellow, medium.	Valspar varnish.
Drop black.	Wall finish, white.
Inside varnish.	Yellow ochre.

CHLOROPICRIN.

Chloropicrin ($\text{C}(\text{NO}_2)\text{Cl}_3$), molecular weight 164.39, has a liquid density of 1.654 under its own pressure at 20°C . Its boiling point is 112°C . The vapor pressure at 20°C . is 18.9 mm. of mercury. It is colorless, very stable, and insoluble in water. It is said to explode on rapid heating, but no mention of any such accident is found in recent reports. Chloropicrin is a lachrymal and respiratory irritant.

Repeated exposure causes increased susceptibility, produces cough, nausea, and vomiting, and in large quantity may cause unconsciousness. Secondary effects are bronchitis, asthma, shortening of the breath, weak, irregular heart action, and gastritis. Liquid chloropicrin has a corrosive action on the skin, producing the effect of a severe burn without blistering. A wound thus made is slow to heal.

Because of the low vapor pressure of chloropicrin, it was necessary to force dry air through it, thereby bringing it to the saturation point, in order to obtain a concentration comparable with that of the gases already discussed. Although water is not soluble in chloropicrin, some moisture collects on the top of the liquid when humid air is passed through it, thereby causing variable humidity. The concentration at saturation is but 1.75 per cent at 20° C. The concentration was determined by absorption in a 2 per cent solution of sodium peroxid in 50 per cent alcohol. Titration by the method employed with phosgene and cyanogen chlorid was used.

Concentrations of from 0.5 to 1.75 per cent and exposures of from seven minutes to two hours were tried on insects.

The minimum lethal dose, with the minimum time, for chloropicrin, as compared with that of hydrocyanic acid, is given in Table 7.

TABLE 7.—Relative insecticidal action of chloropicrin and hydrocyanic acid.

Insects.	Chloropicrin (100 per cent lethal).				Hydrocyanic acid (100 per cent lethal).			
	Con- centra- tion.	Time of ex- posure.	Tem- pera- ture.	Rela- tive humid- ity.	Con- centra- tion.	Time of ex- posure.	Tem- pera- ture.	Rela- tive humid- ity.
Ants (<i>Monomorium pharaonis</i> L.)....	P. ct. 10.5	Min. 7	° C. 20	40				
Ants (<i>Lasius niger</i> L., var. <i>americanus</i> Emery).....					0.2	30	25	40
Ants (<i>Tetramorium caespitum</i> Fab.)....					.2	30	25	40
Aphids (<i>Myzus persicae</i> Sulz.).....	.5	30	21	40	.2	60	24	40
Bedbugs (<i>Cimex lectularius</i> L.).....	1.0	30	23	40	2.0	30	27	40
Beetles, Colorado potato (<i>Leptinotarsa decemlineata</i> Say).....					.5	15	30	40
Beetle, Colorado potato, larvæ.....					.5	15	30	40
Beetles, Flat grain (<i>Laemophylax minutus</i> Oliv.).....	1.5	15	25	40	1.0	60	26	40
Beetles, Potato flea (<i>Epirix cucumeris</i> Harris).....	2.5	15	22	40	.5	7	27	40
Beetles, Sawtooth grain (<i>Silvanus surinamensis</i> L.).....	1.0	30	27	40	1.0	30	28	40
Borers, Grain (<i>Rhizopertha dominica</i> Fab.).....	1.0	30	27	40	1.0	30	30	40
Flies (<i>Musca domestica</i> L.).....	1.5	7	26	40	2.1	7	25	40
Fly larvæ.....					.1	30	25	40
Flv. White (<i>Aleyrodes vaporariorum</i> Westw.).....	1.5	7	21	40	2.1	7	30	40
Mite, Phyllostachys Bamboo (<i>Tarsonemus</i> sp.).....	1.0	7	21	40	.2	60	24	40
Roaches (<i>Plattella germanica</i> L.).....	.5	60	25	40	.2	15	25	40
Spiders, Red (<i>Tetranychus bimaculatus</i> Harvey).....	.5	30	21	40	.2	30	23	40
Weevils, Flour (<i>Tribolium ferrugineum</i> Fab.).....	1.0	60	27	40	1.0	30	34	40
Weevils, Rice (<i>Calandra oryzae</i> L.)....	1.0	120	20	40	4.0	120	28	40

¹ Not minimum lethal dose.

² Impossible to obtain more insects to secure a definite low concentration and exposure.

The results reported in Table 7 show that chloropicrin is more toxic than hydrocyanic acid to some insects, especially toward the stored-product insects. The mites, however, appear to be more resistant to chloropicrin than to hydrocyanic acid.

To check the results obtained by Moore,¹ weevils, both flour and rice (*Tribolium ferrugineum* Fab., *Calandra oryzae* L.) and *Plodia interpunctella* Hbn. larvæ were fumigated with chloropicrin at the rate of 1 pound per 1,000 cubic feet. In the case of each insect, 50 individuals were placed in glass cylinders, which were then covered at both ends with gauze and put in the center of a 2-peck sack of oats where they were treated for 24 hours. On removal, all the insects were apparently dead, and none of them revived during a period of several days.

Germination tests, made on a number of varieties of seeds which had been fumigated with saturated chloropicrin gas for various periods, gave the result shown in Table 8.

TABLE 8.—*Effect of chloropicrin on seed germination.*

Kind of seed.	Germination.			
	Check.	1.75 per cent concentration (temperature, 20° C.; relative humidity, 0).		
		30 minutes.	60 minutes.	120 minutes.
		Per cent.	Per cent.	Per cent.
Alfalfa, Common.....		49.0	42.0	35.0
Barley, Moriart.....		100.0	99.5	100.0
Carrot, Danvers half long.....		74.0	66.0	88.0
Corn, C. I. 119.....		99.5	100.0	99.5
Flax, F. H. B. 29057.....		94.0	94.5	91.5
Muskmelon, Burrell's gem.....		64.5	73.0	70.0
Onion, Australian brown.....		54.0	53.0	40.5
Radish, Scarlet globe.....		98.5	94.5	94.5
Rape, No. 1562.....		92.0	83.5	92.0
Rice, Honduras.....		89.5	95.5	96.0
Soy bean, Biloxi.....		75.0	85.0	76.5
Timothy, No. 29.....		66.0	81.0	92.5
Wheat, C. I. 180.....		97.0	95.5	97.0

Apparently chloropicrin stimulates the growth of rice and timothy and injures somewhat the seeds of alfalfa and radishes. The rest of the seeds showed no marked effects of the treatment.

The results of a series of experiments on *Fusarium*, *Ascochyta*, *Penicillium*, and *Colletotrichum* indicate that chloropicrin can not be used as a fungicide.

¹ Moore, Fumigation with chloropicrin. J. Econ. Entomol., 11 (1918): 357-362.

In order to determine the corrosive effect of the gas, several metals were cleaned and polished and then exposed to chloropicrin in a fumigation box, with the following results:

Concentration of gas.....	0.25 per cent.	1 per cent.
Time of exposure.....	24 hours.	2 hours.
Temperature.....	21° C.	26° C.
Relative humidity.....	30.	30.
Metal.	Action.	Action.
Brass.....	No visible effect.....	Very slight corrosion.
Steel.....	do.....	Do.
Aluminum.....	do.....	No visible effect.
Iron.....	do.....	Do.
Galvanized iron.....	Very slight corrosion.....	Do.
Tin.....	No visible effect.....	Do.
Copper.....	Very slight corrosion.....	Do.
Zinc.....	do.....	Do.

Double coats of a number of paints and varnishes were applied to 2-inch strips of pine and allowed to dry thoroughly, after which they were exposed to chloropicrin in the same manner as the metals. After fumigation, they were examined with a microscope to detect any change in finish, and their color was compared with that of an untreated sample. When exposed for 24 hours, at a temperature of 21° C. and a relative humidity of 30, to a gas of 0.25 per cent concentration, or for 2 hours at a temperature of 26° C. and a relative humidity of 30, to a gas of 1 per cent concentration, no effect was visible in the case of the following materials:

American blue.	Lead in oil.
American vermilion.	Raw sienna.
Burnt sienna.	Red lead.
Burnt umber.	Rose pink.
Chrome green medium.	Valspar varnish.
Drop black.	Wall finish white.
Lampblack.	Yellow ocher.

The action of chloropicrin on fabrics has been determined by Moore.¹

Several varieties of cloth of different colors were exposed to 1 per cent cyanogen chlorid for 24 hours in a fumigation box. The effect on the color was noted, as well as any other injury done. No tensile strength tests were made, but the samples were tested by pulling the treated and the untreated fabrics and comparing the results. The color was not visibly affected, nor could any injury be detected in the following fabrics after treatment:

Satin, fancy (malachite green).	Organdie (rose pink, pale green, light blue, and orange).
Peau de cygne (tobacco brown).	Sateen (royal purple, lemon yellow, cardinal red).
Pongee (natural color).	Voile (flesh pink and lavender).
Surah (gray and white shepherd's plaid).	Gingham (dull gray blue).
Poplin, silk and wool (white).	Gingham, chambray (green)
Satin, cotton back (midnight blue).	Linen, sage green.
Flannel (white).	Linen, imitation (Alice blue, pink, and coral).
Velours (dark brown).	
Poplin, all-wool (black).	
Homespun (brown and white).	

¹ Loc. cit.

ILLUMINATING GAS.

The results of a series of experiments with illuminating gas on the same varieties of insects as were employed in the tests previously discussed, using a concentration of 3 per cent and an exposure for two hours, showed that it is not toxic to insects. Consequently no detailed data are given.

CARBON MONOXID.

Carbon monoxid also proved to be nontoxic to insects at a concentration of 3 per cent and an exposure for two hours. The same varieties of insects were used as in the preceding tests.

SUMMARY.

The results of the action on insects of all the gases tested, with the exception of illuminating gas and carbon monoxid, are given in Table 9.

CONCLUSIONS.

Phosgene is not useful as an insecticide, because of its toxicity toward human beings, its high vapor pressure, the difficulty of controlling it, and its comparatively low toxicity toward insects. Neither does it possess any value as a fungicide.

Arsine has no advantage other than ease of generation, and possesses many disadvantages as an insecticide. Its toxicity toward insects is comparatively low, it is injurious to plants, and has no effect on fungi.

Illuminating gas in concentrations up to 3 per cent and for exposures up to two hours is not toxic to insects.

Carbon monoxid in concentrations up to 3 per cent and for exposures of two hours is not toxic to insects.

Of the gases tested, cyanogen chlorid and chloropicrin give promise of being useful for fumigation purposes. Neither of these, however, can be used in greenhouse fumigation, because of their injurious action on plants. Nevertheless they probably can be used in the fumigation of stored products.

The efficiency of chloropicrin as an insecticide is undoubted. In general, it is more poisonous to stored-product insects than hydrocyanic acid. Other advantages which it possesses are ease of handling and control, low toxicity toward human beings, ease of detection, and noninflammability. Its disadvantages are its adherent quality, which makes it necessary to air the material for some time after it has been fumigated, its corrosive action on metals, its severe lachrymal effect, and its low volatility. The last objection may be partially overcome by pouring the dose required on paper, thereby increasing the evaporating surface.

TABLE 9.—Effect of some toxic gases on insects.

Insects.	Phosgene (100 per cent lethal).				Arsine (100 per cent lethal).				Cyanogen chlorid (100 per cent lethal).				Chloropicrin (100 per cent lethal).				Hydrocyanic acid (100 per cent lethal).			
	Con- centra- tion.	Time of ex- pos- ure.	Tem- pera- ture.	Rela- tive hu- mid- ity.	Con- centra- tion.	Time of ex- pos- ure.	Tem- pera- ture.	Rela- tive hu- mid- ity.	Con- centra- tion.	Time of ex- pos- ure.	Tem- pera- ture.	Rela- tive hu- mid- ity.	Con- centra- tion.	Time of ex- pos- ure.	Tem- pera- ture.	Rela- tive hu- mid- ity.	Con- centra- tion.	Time of ex- pos- ure.	Tem- pera- ture.	Rela- tive hu- mid- ity.
Ants (<i>Monomorium minimum</i> Buckley).....	Per ct. 0.5	Min. 30	° C. 19	19	Per ct.	Min.	° C.		Per ct.	Min.	° C.		Per ct.	Min.	° C.		Per ct.	Min.	° C.	
Ants (<i>Tetramorium caespitum</i> Fab.).....					2.0	60	20	40									0.2	30	25	40
Ants (<i>Lasius niger</i> L., var. <i>americanus</i> Emery).....																	.2	30	25	40
Ants (<i>Monomorium pharaonis</i> L.).....																				
Aphids (<i>Myzus persicae</i> Sulz.).....	1.0	30	31	40	1.0	60	25	40	0.2	30	26	40	10.5	7	20	40				
Bedbugs (<i>Cimex lectularius</i> L.).....	2.0	120	26	40					.1	30	26	40	.5	30	21	40				
Bedbug eggs.....	2.0	120	24	40					1.0	30	27	40	1.0	30	23	40				
Beetles, Colorado potato (<i>Leptinotarsa decemlineata</i> Say).....	4.0	120	30	40					1.0	60	28	40								
Beetle, Colorado potato, larvæ.....	4.0	120	30	40					.5	30	28	40					.5	15	30	40
Beetles, Flat grain (<i>Lacmoph- tacus minutus</i> Oliv.).....	1.0	120	29	40	.5	60	24	40	.5	15	30	40					.5	15	30	40
Beetles, Potato flea (<i>Epiditiz cucumertis</i> Harris).....	1.0	60	30	40	1.0	60	20	40	.5	15	27	40	1.5	15	25	40	1.0	60	26	40
Beetles, Sawtooth grain (<i>Sil- vanus surinamensis</i> L.).....	1.0	120	28	40	.5	60	25	40	1.0	60	27	40	1.0	30	27	40	.5	7	27	40
Beetles, Grain (<i>Rhizopertha dominica</i> Fab.).....	2.0	60	29	40	.5	15	25	40	1.0	60	23	40	1.0	30	27	40	1.0	30	30	40
Flies.....	1.5	7	26	40	6.5	60	21	40	6.1	15	25	40	6.5	7	26	40	1.1	7	25	40
Fly larvae.....	83.0	120	26	40	71.0	30	25	40	6.5	15	24	40					.1	30	25	40
Fly, White (<i>Aleyrodes vapor- ariorum</i> Westw.).....	11.0	30	22	40	.5	30	20	40	.2	7	29	40	1.5	7	21	40	1.1	7	30	40
Lice, Body (<i>Pediculus corporis</i> De G.) eggs.....	93.0	120	23	40																
Mite, Phyllostachys bamboo (<i>Tarsonemus</i> sp.).....	1.5	30	25	40	2.0	60	29	40	.2	30	29	40	1.0	7	21	40	.2	60	24	40
Roaches (<i>Blattella germanica</i> L.).....	1.5	120	27	40	1.0	60	25	40	.5	30	25	40	.5	60	25	40	.2	15	25	40
Roach egg pods.....	3.0	120	30	40	3.0	60	25	40	2.0	60	23	40								

Spiders, Red (<i>Tetranychus bimaculatus</i> Harvey).....	.5	60	31	40	10	3.0	120	29	40	.5	15	28	40	.5	30	21	40	.2	30	23	40
Weevils, Flour (<i>Tribolium ferrugineum</i> Fab.).....	11	4.0	120	23	40	1.0	60	22	40	2.0	60	24	40	1.0	60	27	40	1.0	30	34	40
Weevils, Rice (<i>Calandra oryzae</i> L.).....	8	4.0	120	26	40	.5	60	29	40	12	4.0	27	40	1.0	120	20	40	4.0	120	28	40

¹ Not minimum lethal treatment.

² Supply of insects exhausted.

³ *Musca domestica* L.; *Calliphora vomitoria* L.; *Muscina stabulans* Fall.

⁴ Equal to or less than but not more than.

⁵ *Musca domestica* L.; *Stomoxys calcitrans* L.; *Chrysomya macellaria* Fab.; *Lucilia sericata* Meig.; *Phormia regina* Meig.

⁶ *Musca domestica* L.

⁷ *Muscina stabulans* Fall.

⁸ 90 per cent killed.

⁹ 90.6 per cent killed.

¹⁰ 99 per cent killed.

¹¹ 88 per cent killed.

¹² 96 per cent killed.

As an insecticide, the effect of cyanogen chlorid is practically the same as that of hydrocyanic acid. Its disadvantages are its injurious effect on plant life, low boiling point, slightly corrosive action on metals, and severe lachrymosal effect. Its advantages are that it is active as a fumigant, is easily detected, is not injurious to seeds in doses which are toxic to insects and fungi, and is no more toxic toward human beings than hydrocyanic acid. It is safer to use than hydrocyanic acid, because it can be detected in lower concentrations.

More experiments on the fungicidal aspect are necessary to work out in greater detail the methods of its use. Since it is a dry gas and does not injure the seeds, its use would offer a decided advantage over the present method of treatment for fungi, whereby the seeds are moistened, which sometimes causes germination before it is desired.

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BULLETIN No. 899

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief



Washington, D. C.

December 14, 1920

GIpsy Moth Tree-Banding Material: How To Make, Use, and Apply It.

By C. W. COLLINS, *Entomological Assistant*, and CLIFFORD E. HOOD, *Scientific Assistant, Gipsy Moth and Brown-tail Moth Investigations.*

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INTRODUCTION.

Previous to 1896 various materials, such as gas tar, coal tar, tree lime, raupenleim, bird lime, printers' ink, cotton batting, and some sticky substances, were used on tree trunks to bar wingless adult insects and caterpillars from ascending trees to deposit their eggs or feed upon the leaves. Since that time there have been developed and used in large quantities sticky compounds, some of which are of great merit. The better grades of this material were used extensively in control work against the gipsy moth (*Porthetria dispar* L.) from 1905 until about 1915, but since this time its use has been somewhat restricted owing to the high cost of the material and its application, and to the increase in high-power spraying.

Raupenleim, which is of a greasy nature, was first imported from Germany and experimented with in control work against the gipsy moth by the State Board of Agriculture of Massachusetts in 1892. Thirteen and one-half tons of the material were imported and used

in banding 40,704 trees during that season and the next. The raupenleim used in 1892 was very effectual, but much of the importation of the following year was inferior in quality and the results obtained were not so gratifying. Further use was made of this material, however, in a more limited way by the Massachusetts Board of Agriculture until 1899. A further field test in barring gipsy moth caterpillars was given this material in 1909 from a sample which Dr. L. O. Howard, while in Europe, had shipped to the United States Bureau of Entomology at Boston, Mass. In 1912 Mr. L. H. Worthley, of this bureau, while making gipsy moth investigations in Europe, was impressed with the successful use of it abroad, and had a barrel of the material shipped to the bureau at Melrose Highlands, Mass. While the results from the former sample sent from Germany to the Bureau of Entomology did not meet the expectations of those testing it, general approval attended the results of the latter.

During the winter of 1915, Mr. A. F. Burgess, in charge of moth work for the Bureau of Entomology, sent samples of raupenleim to Dr. J. K. Haywood, chairman of the Federal Insecticide Board, Washington, D. C. These were turned over to Mr. C. C. McDonnell who arranged to have them analyzed and studied by Mr. E. L. Griffin, of the Insecticide Laboratory, with the idea of producing a like or similar compound. Several samples were made and sent to Melrose Highlands, Mass. These were tested and gave good results, consequently 4 tons of the material were made by the Insecticide Laboratory during the spring of 1916 and used in banding against the gipsy moth in New England during that season. The original formula and results secured during these experiments were published by Messrs. A. F. Burgess and E. L. Griffin.¹ Work by the writers in the preparation of this compound has resulted in certain changes in proportion and methods of mixing, which are described in the following pages. The product which gave the most satisfactory results is referred to under the name of "gipsy moth tree-banding material." The formula for making this product is on page 6.

USES OF GIPSY MOTH TREE-BANDING MATERIAL.

It has been the custom in the control work against the gipsy moth to band trees in heavy infestations along roadways, on lawns, and in dooryards where extensive migration of caterpillars is expected or where protection of valuable trees is especially desirable. Bands are now being used extensively at infestations in the border territory by Mr. H. L. McIntyre of this bureau, who has charge of the scouting and extermination work. The infestations considered dangerous in

¹ BURGESS, A. F., and GRIFFIN, E. L. A NEW TREE-BANDING MATERIAL FOR THE CONTROL OF THE GIPSY MOTH. In *Journ. Econ. Ent.*, v. 10, no. 1, p. 131-134, pl. 6-7. February, 1917.

the outside territory are often located on isolated apple or oak trees and in open woodlands which are situated on slopes or elevations where the wind plays an important part in the dispersion of the small larvæ. Infested trees are also frequently located near or in the stone walls so common in New England, and eggs deposited in the stone walls are very difficult to find and to treat. Under such conditions bands are very effective in preventing newly hatched larvæ from crawling out of walls into trees that have been cleared of egg clusters, thus preventing also rapid and long-distance wind spread of the larvæ.

Bands were at one period used quite extensively in heavy infestations of the gipsy moth along roadsides where it was necessary to protect trees upon which the egg clusters had been treated against the ravages of migrating caterpillars from adjoining woodlands. This served to prevent caterpillars from ascending trees that have branches overhanging the road, from which they could spin down by means of silken threads, be caught by passing vehicles, and be dispersed by that means.

MAKING GIPSY MOTH TREE-BANDING MATERIAL.

MATERIALS USED.

- A. Coal-tar neutral oil having a density of 1.12 to 1.15 at 20° C.
- B. Hard coal-tar pitch, melting point about 49° C.
- C. Rosin oil, known as first run "kidney," having a viscosity of 52 at 100° C. tested with a Saybolt universal viscosimeter.

A neutral or nearly neutral coal-tar oil must be used, as coal-tar acids are sometimes injurious to trees.

As the rosin oil is the result of crude distillation, the grade is not constant, varying in color, viscosity, and acidity. Some rosin oils are light to dark brown, some black, others dark blue, and some are possibly of other shades.

Some rosin oils contain more free acid than others, and usually those with the higher acid content give the best results. On the other hand, if too highly acid, the mixture saponifies so quickly that it becomes too thick before the last addition of coal-tar neutral oil is made, with the result that when the latter is added it will not mix properly, thus making a poor product.

The rosin oil that gave the best results was of a medium to dark brown color, having a viscosity of 52 at 20° C. tested with a Saybolt universal viscosimeter and containing 26 per cent free acid. This oil saponified in from 4 to 10 minutes; those which saponify rapidly are not so satisfactory to use.

In some cases where the free acid contents of the rosin oil are low, the mixture will saponify very slowly, and when fully saponified the finished product will be so soft that it will not stand up on the trees, even at moderate temperatures. In order to remedy this, it is necessary to add more rosin oil to bring the acid content up to the required amount, so that the product will set properly and remain intact on the trees during high summer temperatures. On the other hand if this method is used, and it requires very much rosin oil to bring about the proper saponification, the resultant product, which will have a larger percentage of rosin oil, is made tougher, and when placed on the trees will film over much more quickly.

Rosin oils low in viscosity but highly acid, though they set very quickly, will give a product which will not as a rule have body enough to stand up well at high temperatures, while rosin oils with a viscosity of 52 or higher contain about the right amount of acid to saponify the mixture thoroughly and make the resultant product of the right consistency to stand up and remain efficient at high temperatures.

D. Ordinary commercial hydrated lime.

This product, known as hydrated lime, is sold commercially and can be bought in 50-pound bags. If this can not be obtained ordinary rock or quick lime can be used, and this should be slaked with just enough water to make the resultant product a dry powder or hydrated lime. This should be passed through a sieve having 14 meshes to the inch. A coarser mesh should not be used.

EQUIPMENT USED.

The banding material was mixed in a 25-gallon soap kettle (fig. 1), which was equipped with a stirring arrangement, having double paddles turning in opposite directions. The mechanism used to turn the paddles in opposite directions was part of the rear end assembly of a light automobile. The axle shaft turned in one direction and a small length of iron pipe inclosing this shaft to about half way down from the top was so attached that it would turn in the opposite direction. To this axle and iron pipe, respectively, were attached double paddles so shaped that the material was kept moving in all directions, thereby making an even mixture. Two pairs of paddles, A and B, which were attached to the outer shaft, moved in one direction, and C and D, attached to the inner shaft, moved in the opposite direction. This was operated by a belt from the shafting of the machine room in the basement of the storehouse mentioned above. The speed of the machine was timed to allow the paddles to turn 30 revolutions per minute. The kettle used was provided with a steam jacket, but usually no heat was required. At low temperatures both the rosin oil and coal-tar neutral oil become rather thick, and do not mix well,

consequently a small amount of heat is necessary to insure the proper mixture. Also, when the viscosity of the rosin oil is high, it is necessary to apply heat to the mixture in order to thin the rosin oil

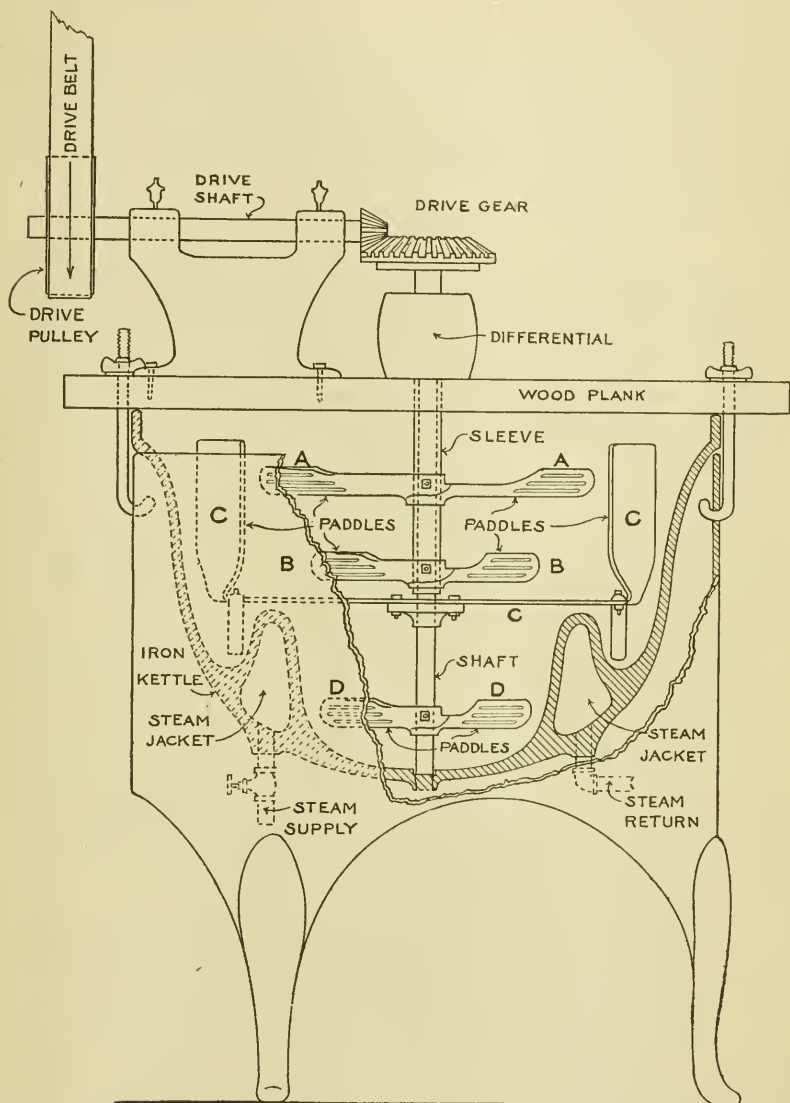


FIG. 1.—Sectional view of kettle or mixer of 25 gallons capacity showing detailed arrangement of transmission and paddles for use in preparing gipsy moth tree-banding material.

so that it will combine properly with the other ingredients. During hot weather it will usually mix well without the addition of heat. In most cases the materials, when being mixed, should be kept at temperatures ranging from 60° to 75° F.

STOCK MIXTURE.

The gipsy moth tree-banding material was made in large quantities as follows: One part by weight of hard coal-tar pitch was placed in a large kettle (fig. 1), to which was added one part by weight of coal-tar neutral oil; heat was then applied to the kettle until all of the pitch had melted and thoroughly mixed with the oil; the kettle was then removed and two more parts by weight of coal-tar neutral oil were added and the contents thoroughly mixed. This product, known as pitch neutral-oil mixture, could be poured and worked after cooling.

FORMULA.

The banding material was mixed as follows: Eighteen pounds of the pitch neutral-oil or stock mixture and 70 pounds of the coal-tar neutral oil were added to the mixing kettle and the stirrer started working. In a few moments 12 pounds of hydrated lime were added slowly to the mixture. When the contents had become of a uniform consistency 50 pounds of rosin oil were added and allowed to mix for a few minutes, or until the contents began to thicken, after which 20 pounds of coal-tar neutral oil were added and the contents allowed to mix thoroughly. The stirring was then stopped and the material poured into containers and allowed to set for two or three days, and by the end of this time the material had set into a semisolid state, of somewhat softer consistency than cup grease.

In cold weather this material is slightly stiff, but it can be applied easily at a temperature of 35° F. At higher temperatures it works very easily.

Most of the material made so far has been used in New England and is best suited to a similar climate. If in a much warmer climate this product proves to be too soft, it may be made harder by slightly increasing the amount of rosin oil and lime. If in a much colder climate it proves too hard, it may be made softer by the addition of a little more coal-tar neutral oil.

If an excess of lime is added to bring the material up to the desired consistency, the product when finished will have more or less of a dry or granular appearance and when placed on the trees will dry out more rapidly and become devoid of the oily surface which is most desired.

If the viscosity of the rosin oil varies, it is necessary to alter the amount used. Figuring from the viscosity of the rosin oil used in this formula, which, as previously stated, is 52 at 100° C., tested with a Saybolt universal viscosimeter, a reduction of 4 pounds of the rosin oil should be made to every 15 points increase in viscosity.

When a reduction of the rosin oil is made, it is also necessary to make an addition of coal-tar neutral oil. Figuring from the amount

used in the formula heretofore stated, which had a specific gravity of about 1.12 at 20° C., an addition of the neutral oil should be made to the amount first added and to the amount last added to the mixer, that is, an addition should be made for every 15 points rise in the viscosity of the rosin oil.

TABLE I.—*Method of adjusting formula to provide for difference in viscosity of rosin oil.*

Viscosity of rosin oil.	Weight of rosin oil.	Weight of coal-tar neutral oil, first addition to mixer.	Weight of coal-tar neutral oil, last addition to mixer.
	<i>Lbs.</i>	<i>Lbs.</i>	<i>Lbs.</i>
52	50	70	20
67	46	72	22
82	42	74	24
97	38	76	26

If the viscosity of the rosin oil falls between these numbers, the amount to be used should be adjusted proportionately, and the amount of coal-tar neutral oil to be used should also be adjusted accordingly.

When the viscosity of the rosin oil rises above 80 it becomes quite thick, and it is usually necessary, especially in cool weather, to apply heat to the mixing kettle in order to have it combine properly with the other ingredients. The amounts of pitch neutral oil mixture and lime to be added remain the same.

COST OF MATERIALS.

The cost of materials used (prices paid by the United States Bureau of Entomology in the fall of 1918) were as follows: The coal-tar neutral oil, 67½ cents per gallon (about 7.1 cents per pound); rosin oil, 59 cents per gallon (about 7.09 cents per pound); the hard coal-tar pitch, \$21 per ton (1.05 cents per pound). Based upon these figures the ingredients composing the tree-banding material cost 6.5 cents per pound. The labor in making the material figured 1.1 cents per pound, the total cost being 7.6 cents per pound. These prices do not include containers.

Metal containers are decidedly preferable to wooden (fig. 2) for storing or shipping the finished product, as the latter absorb some of the oil contained in the mixture.

Over 25 tons of this material had been made by the United States Bureau of Entomology, at Melrose Highlands, Mass., by December 31, 1919, and used in the gipsy moth work in New England.

APPLICATION OF THE BANDS.

PREPARING THE TREES.

In the application of sticky bands to forest and shade trees, the usual method is to scrape off, by means of a tree scraper, the loose scales of bark over a surface of 3 to 5 inches wide at the place the

band is to be applied. In this procedure too much of the outer bark is often removed, or the inner layer is gouged in the operation, resulting in slight injury to the bark. It is very necessary preparatory to applying the sticky bands to secure a smooth surface. If not, the material, which sticks securely to the paddle used for applying, picks up much of the loose bark and in shaping the bands these particles are left on the surface and later form bridges for the caterpillars to cross. It is essential to scrape such bark as white oak, ash, or old apple trees both for the purpose of securing the desired smooth surface and to save material which would otherwise be wasted by working into the crevices. The sticky material is ordinarily applied by means of a paddle made of hard wood 2 to 2½ inches wide and with edge beveled obliquely for the convenience of the operator.

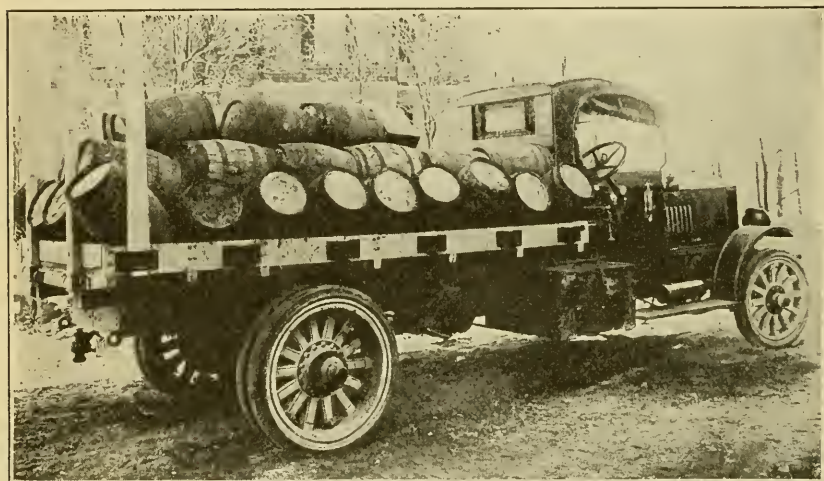
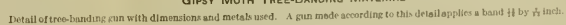


FIG. 2.—Truck containing 1½ tons of gipsy-moth tree-banding material, part of 25 tons made by United States Bureau of Entomology between 1917 and 1919.

No scraping of the bark is necessary in applying gipsy moth tree-banding material unless such bark is very loose and scaly, as on an old white oak or apple, it only being necessary to rub the loose bark off with the hand.

The material is most economically and conveniently applied by means of a special gun (Pl. I). This consists of a tin cylinder 3 inches in diameter and 8 inches long, the lower end being closed except for a small opening over which the nozzle or mold is attached by means of solder. The gun is also provided with a removable plunger. After the material is put in it is forced through the nozzle by the plunger, which is manipulated by means of two handles. The handles work similarly to those of a pair of large shears (one being riveted stationary to the cylinder). The other



handle is provided with a ratchet at the end, which meshes with dogs on the guide of the plunger. The nozzle, which is also made of tin, is attached to the base of the cylinder and measures 1 inch long over all, projecting $\frac{9}{16}$ inch beyond bottom of cylinder. It is $\frac{3}{8}$ inch in depth at the bottom of the cylinder, tapering to $\frac{1}{4}$ inch at the tip, the space between these measurements being open on one side and end. The width is $\frac{7}{8}$ inch. A nozzle of these dimensions molds a band $\frac{13}{16}$ by $\frac{7}{32}$ inch.

The gun when filled holds from 1.6 to 2 pounds of the material. The material is easily transferred to the gun by means of a wooden

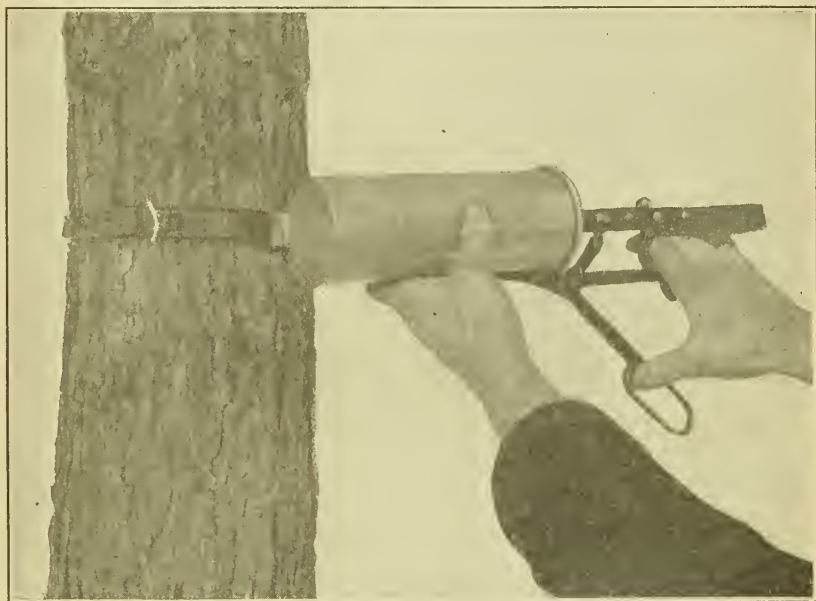


FIG. 3.—Tree-banding gun in position during application of band of gipsy moth tree-banding material. Note the square edges of this band.

paddle, or better by an implement made of thin steel plate $2\frac{1}{2}$ inches wide and 10 inches long. The plate should be cut down so that a handle 4 inches long is provided at one end.

The bands should be applied (fig. 3) to the trunks of trees 5 to 8 feet above the ground when the infestation of caterpillars is on private estates where there is danger of animals, such as horses or cows, rubbing into them. In the border territory of the gipsy-moth area where extermination of colonies is intended it is sometimes more advantageous to place the bands low down on the trunks of trees. This is done to prevent the small larvæ crawling up from the ground and clustering on the trunks of the trees in positions from which they may be more easily dislodged and dispersed by the wind.

It might be added that in some cases men applying gipsy moth tree-banding material have received temporary injury to the face and hands, particularly the latter. In such cases the operator experienced a burning followed by soreness similar to that of sunburn, the skin later peeling off to some extent. Not more than 50 per cent of the men using the material experienced any difficulty in this respect. It is possible that injury to those susceptible might be prevented by coating the skin with vaseline immediately before using the banding material.

SIZES AND SHAPES OF BANDS USED.

Experiments have been conducted in the field to determine what size, shape, and thickness of bands are most efficient (fig. 4). A gun, used in molding bands on the trees, was so arranged that nozzles of various sizes could be attached to it. Bands rectangular in shape,

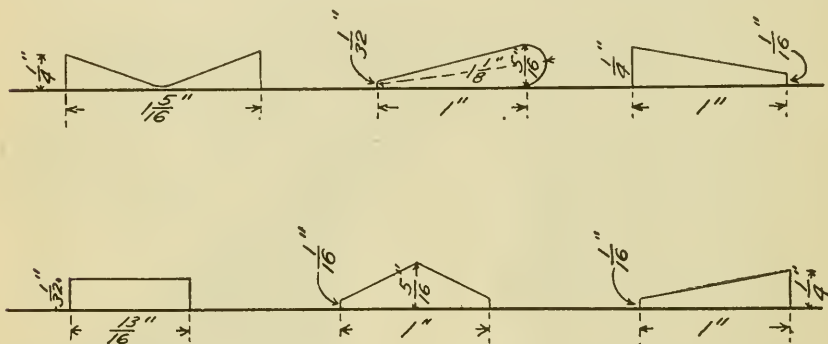


FIG. 4.—Showing some of the forms of bands of gipsy moth tree-banding material with which experiments were made. The rectangular form proved most successful.

varying from $\frac{7}{8}$ to $2\frac{1}{2}$ inches in width were tested, and some having a thickness of $\frac{1}{16}$ inch at top, $\frac{1}{4}$ inch at bottom, and $1\frac{3}{16}$ inches broad; others $\frac{1}{16}$ inch at top and bottom and $\frac{5}{16}$ inch in middle, 1 inch wide; also some $\frac{1}{32}$ inch at top, $\frac{5}{16}$ inch near bottom, with rounded surface on lower edge, and a type having a thickness at top and bottom of $\frac{1}{4}$ inch, sloping to a thin smear in the middle and $1\frac{5}{16}$ inches wide.

The rectangular bands $1\frac{3}{8}$ inch broad and $\frac{7}{32}$ inch thick proved both economical and efficient where the infestation of caterpillars was not too severe. Bands of this size have been used on a large scale in the extermination work against the gipsy moth in the border territory, and were found to be the most satisfactory under average conditions. Bands of these dimensions are very efficient when attended once or twice weekly during the active caterpillar season—the surface refreshed, the bridges removed, and the caterpillars beneath killed. The frequency with which the bands should be attended depends upon the degree of infestation, and too much stress

can not be laid on the care of the bands during the caterpillar season. The mere presence of the bands, regardless of their condition, will not be effective in barring caterpillars. On the other hand, if regular and frequent care can not be given the bands during the heavy caterpillar season, it is sometimes advisable to use broader bands of $1\frac{1}{4}$ or more inches wide. Also double bands, each $\frac{1\frac{3}{8}}{2}$ by $\frac{7}{32}$ inch, which can be applied with the regulation tree-banding gun by merely encircling the tree twice, are very effective where the infestation is extremely heavy. Bands should not be applied of more than $\frac{1}{4}$ inch thickness, as the weight of the material causes the bands to separate and slide down, especially on smooth-bark trees, unless such bands are $1\frac{1}{2}$ inches or more in breadth.

COMPARISON OF COSTS AND TIME REQUIRED TO SCRAPE TREES AND APPLY STICKY BANDS TO THAT OF GIPSY MOTH TREE-BANDING MATERIAL.

A comparative test was made in applying 25 pounds each of sticky banding material and the gipsy moth tree-banding material. A band of each kind of material was applied to the same trees, namely, shagbark hickory, white oak, black oak, red maple, and white pine. Each tree was calipered so that the linear feet of bands applied could be figured.

The sticky material banded 212 trees with an average diameter of 7.5 inches. These were applied with a 2-inch wooden paddle and were about $2\frac{3}{4}$ inches wide and $\frac{1}{8}$ inch thick. One hour and 42 minutes were required to scrape the trees and 3 hours and 54 minutes to band them, making a total of 5 hours and 36 minutes. Four hundred and nineteen linear feet of bands were applied out of 25 pounds of this material.

Twenty-five pounds of the gipsy moth tree-banding material were then applied with the gun, which molded a band $\frac{1\frac{3}{8}}{2}$ inch wide and $\frac{7}{32}$ inch thick. One hundred and forty-five trees averaging 7 inches in diameter were banded. An average of 1.63 pounds was put in the gun each time it was filled. Fifty minutes were consumed in filling the gun and 90 minutes in applying the bands, or a total of 2 hours and 20 minutes. Two hundred and sixty-three linear feet of bands were applied with the 25 pounds. No extra time was required or allowed for preparing the trees previous to banding, as only a quick rub with the hand is necessary on trees where the bark is loose and scaly.

The prices of materials and labor in 1918 were as follows: Sticky banding material in large lots, 34 cents per pound; gipsy moth tree-banding material, 7.6 cents per pound; and labor for applying, 40 cents per hour. Comparisons on this scale per linear foot after bands had been applied were as shown in Table II.

TABLE II.—*Costs of gipsy moth tree-banding material together with application, 1918.*

	Price per pound.	Width and thickness of bands.	Cost of material and application per linear foot.
	<i>Cents.</i>	<i>Inches.</i>	<i>Cents.</i>
Sticky material.....	34	$2\frac{3}{4}$ by $\frac{1}{8}$	2.56
Gipsy moth tree-banding material.....	7.6	$1\frac{1}{2}$ by $\frac{3}{8}$	1.08
Gipsy moth tree-banding material.....	7.6	$1\frac{1}{4}$ by $\frac{3}{8}$	1.19
Gipsy moth tree-banding material.....	7.6	$1\frac{1}{4}$ by $\frac{5}{8}$	1.42

It will be noted from Table II that with two samples of bands the cost of material plus the price of application of the gipsy moth tree-banding material is slightly less than one-half, while with another sample it is slightly more than one-half of the cost of the sticky material. This feature coupled with its efficiency in barring many species of caterpillars from ascending trees warrants its adoption where other conditions are favorable.

VALUE OF BANDING TREES IN WOODLANDS, ALONG FENCES, OR NEAR STONE WALLS.

When open woodlands or those that can be cleared of small growth and underbrush become badly infested with the gipsy moth it is sometimes practicable to save the trees by applying creosote to the egg clusters and subsequently banding the trees with gipsy moth tree-banding material (Pl. II). In treating the egg clusters by hand methods in such infestations, there are usually a varying number overlooked that were deposited on stones or trash on the ground. The larvæ that hatch from such egg clusters are prevented from ascending the trees by the bands, and numerous larvæ that are constantly spinning threads and dropping from foliage above are barred from reascending. The bands are effective against the small larvæ that lodge in trees as a result of wind spread only when such larvæ later spin down or drop to the ground.

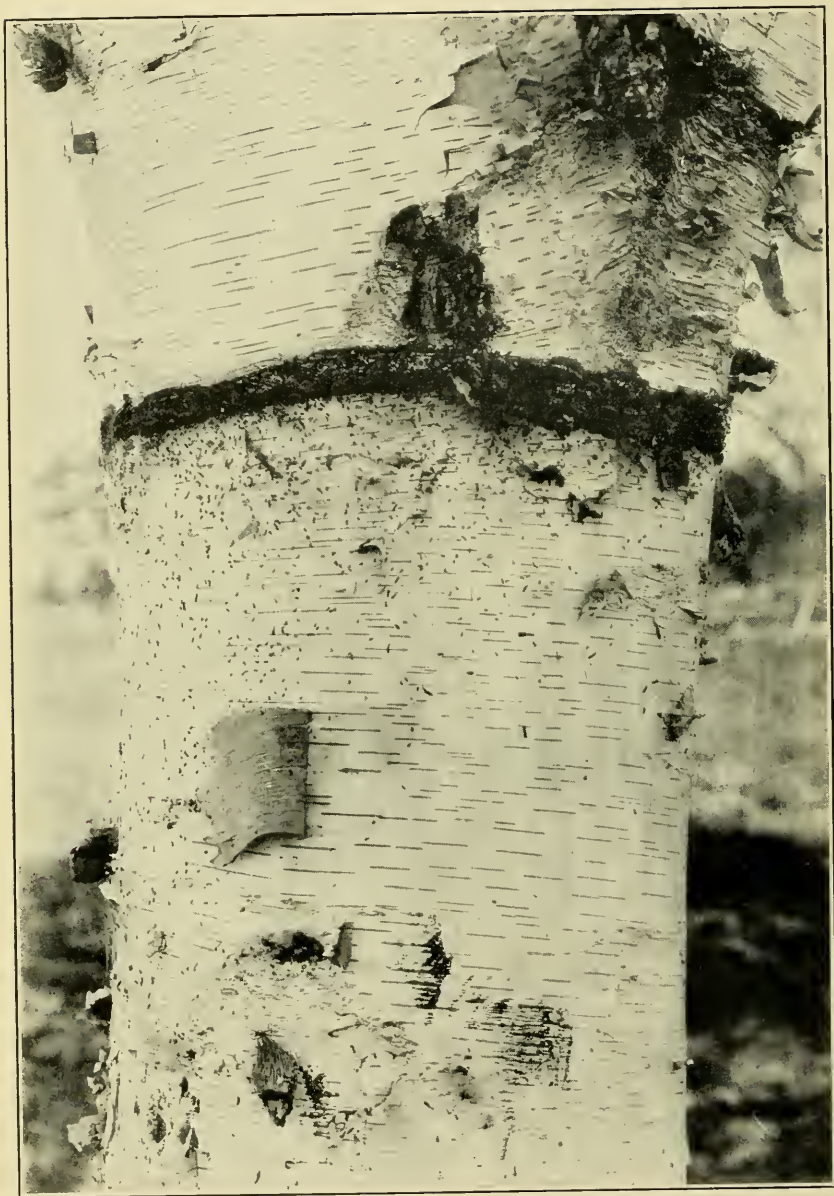
Sections of woodlands not too heavily infested with the gipsy moth can sometimes be saved from defoliation by applying bands of this material and keeping them in good condition throughout the caterpillar season (Pl. II). If the infestation in woodland to be dealt with is severe, it is advisable to apply creosote to all egg clusters that can be reached and subsequently to band with gipsy moth tree-banding material.

Trees located along roadsides or near stone walls after once being cleaned of egg clusters may well be banded to prevent migrating larvæ that come out of walls or low brush from finding their way to the foliage (Pl. III).



GIPSY MOTH TREE-BANDING MATERIAL

Woodland trees badly infested by the gipsy moth, 1919. No spraying or treating egg clusters by hand. Trees on right not banded, those on left banded with gipsy moth tree-banding material and saved from defoliation.



GIPSY MOTH TREE-BANDING MATERIAL

Showing band $\frac{1}{8}$ by $\frac{7}{8}$ inch barring small gipsy-moth caterpillars on white birch. Many small larvæ are embedded and dead in lower edge of this band.



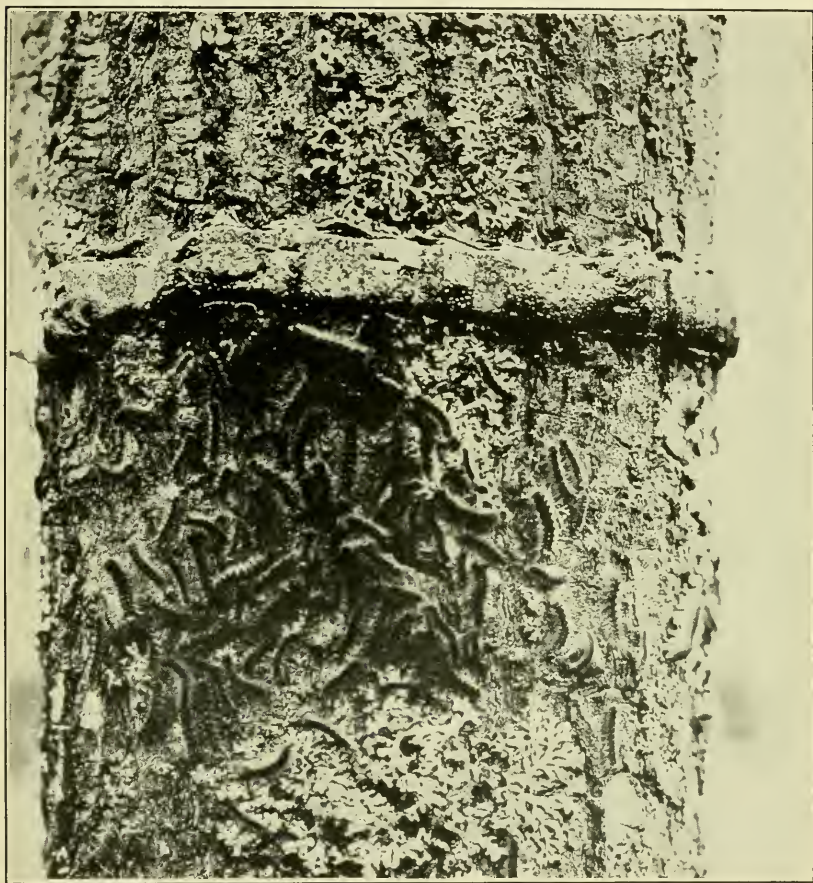
GIPSY MOTH TREE-BANDING MATERIAL

Narrow band has been re-treated by working over surface with putty knife. Check band above of sticky material with space free from caterpillars between, indicating efficiency of lower band. Note active caterpillars ascending to bands, then spinning down.



GIPSY MOTH TREE-BANDING MATERIAL

About 1,500 gipsy moth caterpillars estimated to be on lower part of trunk of this tree and barred by gipsy moth tree-banding material. This band was attended and kept in good condition because of the heavy infestation.



GIPSY MOTH TREE-BANDING MATERIAL

(Narrow band without treatment barring half-grown gipsy moth caterpillars efficiently in a moderate infestation.

PRACTICABILITY OF TREATING GIPSY MOTH EGG CLUSTERS AND OF BANDING TREES VS. POWER SPRAYING.

If a wooded area badly infested with the gipsy moth can be sprayed under proper weather conditions during the early feeding periods of the small larvæ, the results are usually very satisfactory. On the other hand, if there is a lack of power-spraying outfits in the vicinity or the work is slowed up by weather conditions until three-fourths or more of the foliage of the trees has been consumed, it is then evident that other methods should have been resorted to earlier in the season. Woodland spraying in 1916 cost about \$5.50 per acre where large areas were involved.² It is estimated that the cost per acre in 1918 was \$10.25, owing to increased cost of materials and labor. A further increase occurred in 1919.

The cost of banding an acre of woodland trees free from underbrush with gipsy moth tree-banding material in 1918 was \$5.29. There were 269 trees per acre averaging 7 inches in diameter. The estimated cost of treating the egg clusters on these trees in 1918, provided the infestation was of a medium degree, is \$8, making a total of \$13.29 for treating and banding.

Spraying in 1918, in a wood lot that had been thinned, cost \$3.04 less per acre. There are many factors to consider with the two methods of controlling infestations of the gipsy moth; for instance, spraying, to be effective, must be done within one month (about June); treating of egg clusters may be done between August and April, inclusive (nine months); and banding may be done during two or three months in the late winter and early spring. No definite recommendations can be given for localities and conditions in general, and these figures are merely to assist one in deciding upon a course of procedure that best suits the particular conditions.

RESURFACING OLD BANDS OF GIPSY MOTH TREE-BANDING MATERIAL.

Several experiments have been conducted to obtain data on the best method of resurfacing bands one or more years old (Pl. IV). Turpentine, coal-tar neutral oil, and kerosene have been applied with a brush to old bands in the early spring. These oils tend to dissolve the hardened surface, but the effect lasts only about one month or less. New gipsy moth tree-banding material was dissolved in these oils and the mixture painted on the surface with slightly more lasting results than in the case of the former method. The latter method was made more efficient by the use of a putty knife or small wire sink brush (Pl. V), which thoroughly stirred up the surface of the old bands to one-half their depth. Another efficient

² WORTHLEY, L. H. SOLID STREAM SPRAYING AGAINST THE GIPSY MOTH AND THE BROWNTAIL MOTH IN NEW ENGLAND. U. S. Dept. Agr. Bul. 480. 1917.

method was to use the putty knife alone, and with it thoroughly work up and renew the old surface.

After bands have remained on trees for one or more years it is often advisable to resurface with the special gun. The bands shrink in dimensions after being applied more than a year so that a nozzle of the same size as was originally used fits over them, thereby applying a thin smear of the material to all exposed sides. One pound of the material will resurface from 25 to 30 linear feet against 10.5 at first application when a nozzle $\frac{7}{8}$ by $\frac{1}{4}$ inch is used in each case. This is the most efficient method of resurfacing known and leaves the bands in practically the same condition as when they were first applied.

BEHAVIOR OF CATERPILLARS BENEATH GIPSY MOTH TREE-BANDING MATERIAL AND ITS EFFECT UPON THOSE CROSSING BANDS.

The first samples of gipsy moth tree-banding material were tested in 1915. At that time the consistency of the material was quite stiff and caterpillars frequently crossed the bands in areas that had partly dried or filmed over on the surface. The idea as conveyed by the Germans in 1912, when a quantity of raupenleim was imported for experimental purposes, was that the nun moth (*Lymantria monacha* L.) and the gipsy moth (*Porthetria dispar* L.) were barred beneath the bands from their dislike of the tar odor emitted by the compound. Some experimenting and many observations have been made to ascertain if the guiding sense in preventing caterpillars crossing bands was smell or touch. Rather hard and soft mixtures with varying degrees of odors and substitutions for the coal-tar odor have been made with pine tar and other ingredients. Whenever the material was quite stiff, regardless of the odor, the caterpillars frequently crossed or rested on or near the bands (Pl. VI). Gipsy-moth caterpillars were seen repeatedly to go up to bands and touch them either with the head pencils of hairs or mouth parts, or walk into them. If the surface of the bands was soft, oily, greasy, or sticky, affording discomfort to the touch or making it impossible to secure a footing, the caterpillars usually turned back. As many as 97 to 99 per cent of the caterpillars in a heavy infestation were barred on some trees by the soft, oily, gipsy moth tree-banding material used in 1919 (Pls. IV, V).

Many caterpillars, especially the younger stages of the gipsy moth, in attempting to cross or when blown into the bands by the wind, quickly die from the effects of the material covering the ventral portion of the body and entering the spiracles. The percentage of larvæ killed in this manner is very high. There were from 150 to 200 small caterpillars dead in the oily surface of each of a few bands in a heavy infestation in 1919 with from 1,500 to 2,000 barred by the same bands. Large larvæ of several species are also killed from effects of the ma-

terial penetrating the body and spiracles of those venturing into the bands.

EFFECT ON BARK OF TREES.

Several experiments have been conducted since 1915 to determine the extent of injury, if any, to the bark of forest, shade, and fruit trees that were banded. Trees were selected with rough and smooth bark, as also peach and apple trees of various ages. In no case was material injury done to the bark with the gipsy moth tree-banding material, the bands being 1 to 2 inches wide. The oil of the bands sometimes penetrates $\frac{1}{2}$ to $\frac{3}{4}$ inch deep on rough-bark trees. Wherever slight surface injury was noted from the penetration of oils, new cells formed in the cambium layer, which gave the bark a slightly swollen appearance at that point. Such slight local injury did not affect the growth or vigor of the trees, or the production of fruit in the case of bearing fruit trees.

Bands 6 to 10 inches wide were placed on peach trees aged from 1 to 15 years. These were applied at the base partly beneath the surface of the soil with the idea of noting injury to the tree should this material prove effective in preventing egg deposition of the peach-tree borer (*Sanninoidea exitiosa* Say). No material injury was noted to the bark save the slight local killing of cells in the outer bark, as was cited above with the forest and fruit trees. This was overcome by the growth of new cells in the cambium layer of the bark. The vigor and fruiting of the trees were not impaired so far as could be detected.

VALUE OF BANDING APPLE TREES LOCATED NEAR WOODLAND INFESTED BY THE GIPSY MOTH.

Many apple orchards or scattering apple trees in New England are located near or bordering on woodland infested with the gipsy moth. After the egg clusters on such trees have been treated with creosote a reinfestation the same season sufficient to damage or defoliate the trees badly often occurs. This condition is brought about by wind-spread of newly hatched caterpillars and the migration into the trees of small larvæ that hatched in near-by hidden places and of larger caterpillars which crawl from the woodlands. This condition can be relieved by spraying with arsenate of lead just after the caterpillars have hatched and once or oftener during the active feeding season. The owner of a small number of apple trees does not usually possess a spraying outfit that will cover large apple trees thoroughly and he is obliged to depend upon the local town power sprayer or private jobber for this work. The operators of such sprayers always have a large amount of work to do with the equipment at hand, consequently many orchards are sprayed late in the season after caterpillars have almost defoliated them, or they are not sprayed at all.

This condition may be greatly relieved by the application of bands of gipsy moth tree-banding material (Pl. VII). If apple trees are located from 50 to 400 feet or more from a badly infested woodland they are liable to severe reinfestation early in the season. If spraying can not be done it has been suggested that relief might be had by shaking the half-grown caterpillars from the trees that have little or no fruit by the use of a long pole to one end of which an iron hook is bolted. If this is done, the upper limbs should be shaken first followed by those beneath. The caterpillars removed in this manner will be prevented from reascending the trees by the bands and may be killed beneath them.

Banding of apple trees is also sometimes advisable together with spraying if the trees are located in an especially dangerous position with regard to infestation. All cavities should be tinned or cemented before bands are applied. It is usually advisable to apply spray instead of bands to very young apple trees 8 years old or less, as such trees can be readily sprayed with any hand outfit.

SPECIES OF INSECTS AGAINST WHICH GIPSY MOTH TREE-BANDING MATERIAL IS EFFECTIVE.

Experiments have been conducted in the laboratory and in the field with several species of insects for information as to which native species of larvæ and adults this material might be effective in barring. Through cooperation the material was tried in Nova Scotia against adults of the fall cankerworm (*Alsophila pometaria* Harr.) by Prof. W. H. Brittain, who reports rather unfavorable results in barring that species. He states that where the infestation was not too heavy the bands worked fairly well, but where the moths appeared in enormous numbers, as was frequently the case, bands 6 inches wide were bridged and crossed in a very short time. It is apparent that for the fall cankerworm the formula used for spring and summer banding against the gipsy moth should be modified so that it will remain soft during fall temperatures, at the time the cankerworms are active, and thus be more effective.

Dr. A. L. Quaintance, of the Bureau of Entomology, had some of the material tested on peach trees at Vienna, Va., against the peach-tree borer (*Sanninoidea exitiosa* Say). He states that while "no injury or ill effects to the trees could be noted after one year, it was only moderately successful in controlling the insect." The material was also tried in New Jersey on peach trees against the above insect by Mr. Alvah Peterson, who applied the bands 4 to 8 inches wide at the base of trees 10 years old or more. He reports that "when the trees were wormed during the fall of 1919 the check trees showed a total of 39 larvæ ($\frac{1}{4}$ to $\frac{3}{8}$ inch in length) while the treated trees showed only 2 larvæ below the bands. It was noted,



GIPSY MOTH TREE-BANDING MATERIAL

Apple orchard which was badly infested with the gipsy moth: egg chusters were treated by hand and bands applied to trees on right excepting one in right foreground. Note condition of trees not banded, on left.

however, that in the treated trees a greater infestation above the bands was present than in the check lot. It is probable that the larvæ were repelled by the material, consequently they entered the tree above ground. As to the fate of these larvæ that enter the tree above ground, I am not certain. I am of the opinion, however, that many and probably all of them will be killed by winter conditions."

The peach-tree borer is not a pest of first importance in Massachusetts, and the experiments conducted on peach trees by the writers consisted mainly of banding the trees and noting the effect on the bark, the vigor of the trees, and the fruiting. Trees of from 1 to 15 years of age were banded and under observation from 1 to 4 years, and no material injury was noted as a result of the bands.

Observations were also made on a number of species of larvæ found in woodlands where bands were applied. The following species of larvæ were barred or ventured into the bands and were unable to free themselves:

- Gipsy moth (*Porthetria dispar* L.).
- Brown-tail moth (*Euproctis chrysorrhoea* L.).
- White-marked tussock moth (*Hemerocampa leucostigma* S. & A.).
- Rusty tussock moth (*Notolophus antiqua* L.).
- Forest tent caterpillar (*Malacosoma disstria* Hbn.).
- Checkered tussock (*Halisidota tessellaris* S. & A.).
- Fall webworm (*Hyphantria cunea* Dru.).
- American silkworm (*Telea polyphemus* Cram.).
- Fall cankerworm (*Alsophila pometaria* Harr.).
- Spring cankerworm (*Paleacrita vernata* Peck.).
- Snow-white linden moth (*Ennomos subsignarius* Hbn.).
- Ashen pinion (*Xylina antennata* Walk.).

There were also some other species of geometrid, noctuid, tortricid, and tenthredinid larvæ that were barred by these bands.

Some other species were inclosed in trays at the laboratory containing bands of gipsy moth tree-banding material at the top and their behavior observed for a period. The following species were barred, or upon venturing into the bands were unable to free themselves from it:

- Salt marsh caterpillar (*Estigmene acerata* Dru.).
- Green clover worm (*Plathypena scabra* Fab.).
- Red-humped apple caterpillar (*Schizura concinna* S. & A.).
- Milkweed butterfly (*Euchaetias cyle*, Dru.).
- Saddled prominent (*Heterocampa guttivitta* Walk.).
- Tent caterpillar (*Malacosoma americana* Fab.).

CONCLUSIONS AND RECOMMENDATIONS.

For control of the gipsy moth and several other species of tree-foliage-feeding caterpillars with similar habits, gipsy moth tree-banding material may be used to great advantage. The cost of mak-

ing and applying this material is 1.08 to 1.42 cents per linear foot (depending upon the width of bands used) whereas the sticky compounds on the market cost 2.56 cents per linear foot. An additional feature is that bands of this material may be retouched or resurfaced and kept in working condition each year with very small cost. Its efficiency in barring caterpillars also compares favorably with the sticky material.

If small apple orchards are to be protected where there is a severe infestation of the gipsy moth and where it is impossible to have such orchards sprayed at the proper time, the egg clusters may be treated by hand and gipsy moth tree-banding material applied economically and with good results.

Injury to the bark of trees is negligible and in no case has there been any more injury noted than with the best banding materials now on the market. It is not advisable, however, to band very young fruit trees directly, as a slight thickening of the bark takes place at that point, which does not add to the beauty of the tree; furthermore insect attacks on trees of this size can be handled more advantageously by spraying.

The width of the band to be used against tree-climbing caterpillars can only be determined by the degree of infestation but it is usually not practicable to apply a band of smaller dimensions than $\frac{1\frac{3}{8}}{16}$ by $\frac{7}{32}$ inch in order that sufficient material be used so that the bands will not dry out too quickly. Bands of these dimensions were found to be the most economical and practical in the extermination work against the gipsy moth in the border territory and are recommended where caterpillar infestations are light or of a medium degree. Double bands of the above dimensions or broader bands, $1\frac{1}{4}$ inches wide or more, will be necessary only when the infestation is extremely heavy. The bands are economically and conveniently applied by the use of a pressure gun made for the purpose.

Caterpillars are barred by gipsy moth tree-banding material when the latter is in good condition, making it a physical impossibility for them to cross. The softness and greasiness of the material are such that large proportions of small larvæ venturing into it become entangled, embedded, or so smeared with oil that death results.

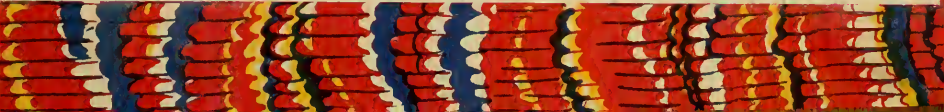
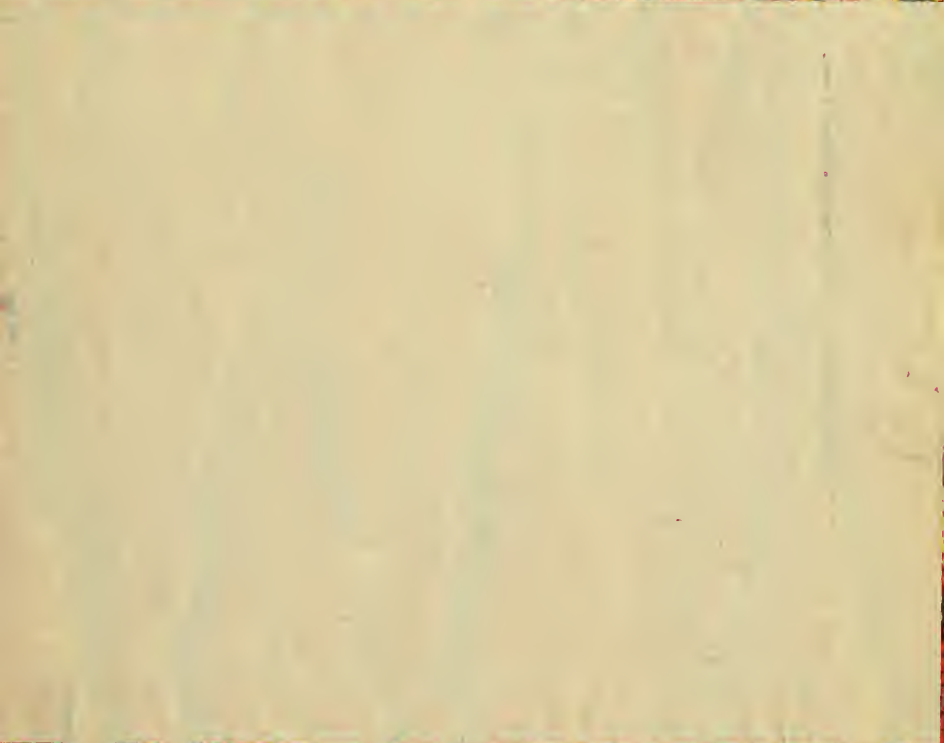
Observations have been made on some insects other than the gipsy moth against which this material might be effective, and it is probable that its use should give equal protection against some of them.

If an organization for insect control work should require large quantities of this material annually, it should equip itself with apparatus for making same. On the other hand, for the owner of a few apple and shade trees it would not be so profitable to make the material on a small scale, although it can be readily done.

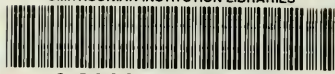
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